Exploring a Carbon Strategy for a Public Forest Products Company in Canada

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Abstract

As forest companies in Canada are struggling to come through a period of record low commodity prices, US exchange rate challenges, and worldwide recession, it is unlikely that a carbon strategy would be a top priority. This paper explores the reality that even as a company operates in a harsh business environment, a carbon strategy is helpful in moving to a more sustainable and financially competitive future. In the context of stakeholder theory and competitive forces both inside and outside the company's industry, there is evidence to show that moving toward a low carbon future is in their best interest over the long term. Considering this, the study looks at the possibility of direct investment in forestry carbon projects from a financial perspective. Specifically, the analysis is based on hypothetical afforestation, fertilization, and select seed projects with harvesting treatments based in the interior of British Columbia. The results indicate that due to the substantial uncertainty and poor expected returns, forest carbon projects may not be a wise investment for forest companies at this time. However, there are various steps that companies can make to transition themselves to a low carbon future. These include carbon footprinting and the development of green programs, targets, and goals within the company's operations. These actions can lead to first mover advantages within the forest industry and prepare the firm for more onerous demands in the future. These demands would include regulatory emission constraints or preparing for the implementation of a cap and trade system.

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Introduction

A Harris-Decima poll held in 2009 suggests that nearly two thirds of Canadians agreed that, "Climate change is mankind's defining crisis, and demands a commensurate response."[1]

Global warming is widely believed to be accelerated by the emission of greenhouse gases (GHG). While several types of gaseous compounds contribute to the greenhouse effect, the most predominant of these gases in our atmosphere is carbon dioxide ($C0_2$). Between 1970 and 2004 the annual emissions of $C0_2$ into the atmosphere grew by about 80% which far exceeds the variations in historical $C0_2$ cycles (IPCC 2007). In an effort to combat the human contribution to this problem, nations around the world are acknowledging the problem and taking steps to ensure that present and future emissions of $C0_2$ will decline. As forest companies have access to a renewable energy source in the form of wood fibre and the capabilities to sow, plant, and tend trees cost effectively, there may be inherent competitive advantages and the potential to profit from climate change policy through carbon markets or avoiding administrative penalties for carbon emissions.

In terms of public policy, one method to curb emissions is through taxation. However, a more popular approach is to move toward a market-based system commonly known as "cap and trade". The premise of this system is that targets for future emission reductions are scaled down from a baseline year. For example, under the 1992 United Nations Framework Convention on Climate Change, the Kyoto Accord brought an agreement

[1] http://www.theglobeandmail.com/news/national/climate-change-seen-as-planets-defining-crisis-poll/article1382640/ accessed April 22, 2010

among developed signatory countries to reduce greenhouse gas emissions by 5% from a 1990 baseline level, and is effective from 2008 through 2012[2].

The basic premise is that the total emissions for each country are capped to meet the overall target. To accomplish this goal, these nations would then require industries and/or specific companies meet emission reduction targets. A given company then has a number of options to meet these targets depending on the specific design of the regulatory system:

1) **Reduce their emissions** to fall under their allowable amounts. This is typically either done through a change to cleaner technology and/or by reducing output.
2) **Develop "offsetting" projects** that either sequester carbon or replace energy produced by burning fossil fuels with a renewable energy source in order to balance emissions that go beyond their cap.
3) **Purchase carbon credits** in order to balance emissions that go beyond their cap. These credits are established from carbon offset projects.
4) **Purchase carbon permits** from other companies that are below their allowable thresholds.
5) Exceed their cap and **pay administrative penalties**.

In order to continue to address climate change beyond 2012, the UNFCCC Conference of Parties (COP 15) was held in Copenhagen, Denmark in December 2009. While some had hoped for a more inclusive agreement with enforceable targets, the result was a non-

[2] http://unfccc.int/kyoto_protocol/items/2830.php/ accessed April 22, 2010

enforceable agreement, the Copenhagen Accord[3], which was a disappointment to many observers. In fact, based on a survey of 4767 respondents, 70% were either "dissatisfied" or "very dissatisfied" with the outcome of the event (Tvinnereim and Roine 2010). As the conference was held against the backdrop of a lingering world recession, some of the major sticking points continued to be the transfer of wealth from richer to poorer countries and a lack of consensus on what the pace of emission reduction should be. One of the successes of the conference was an official recognition of "reduced emissions from deforestation and degradation" (REDD). Perhaps even more significant was the agreement by developing countries to submit detailed and reviewable inventories to the same standard as developed countries[4]. The significance of the latter is the establishment of a common platform from which to build a future comprehensive international cap and trade system. The final result was an agreement signed by several nations as a commitment to work toward emission reductions, but with no firm reduction targets (Hamilton et al. 2010).

Problem Definition

Business leaders are beginning to consider climate change no longer as an environmental issue but rather a market transition (Hoffman 2008). As in every industry, the forest sector must also look to the future in this way. Companies that pursue a carbon strategy

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[3] http://unfccc.int/meetings/cop_15/items/5257.php accessed April 22, 2010
[4] http://docs.google.com/viewer?a=v&q=cache:lp_RKkIW-EEJ:unfccc.int/resource/docs/2009/cop15/eng/l07.pdf+cop15+results+reporting&hl=en&gl=ca&pid=bl&srcid=ADGEESiZNwiuqKEdTaTUUCBGEqIt-aZg3hOhj95ofd7k8bcGc1kiLthXWFqJ3kB5R90Ra53X-eIVs4nhXkqOWFzFIMELu4Slo9NBQtYYMq9lXE7zIaPcvJf-fxqfh2DuokJ03eVmHZ2K&sig=AHIEtbTcafT02ZvJNv56LXJzw-zY3W2hMQ accessed April 23, 2010

will be faced with decisions regarding their methods and level of engagement which will have impacts on all aspects of their business.

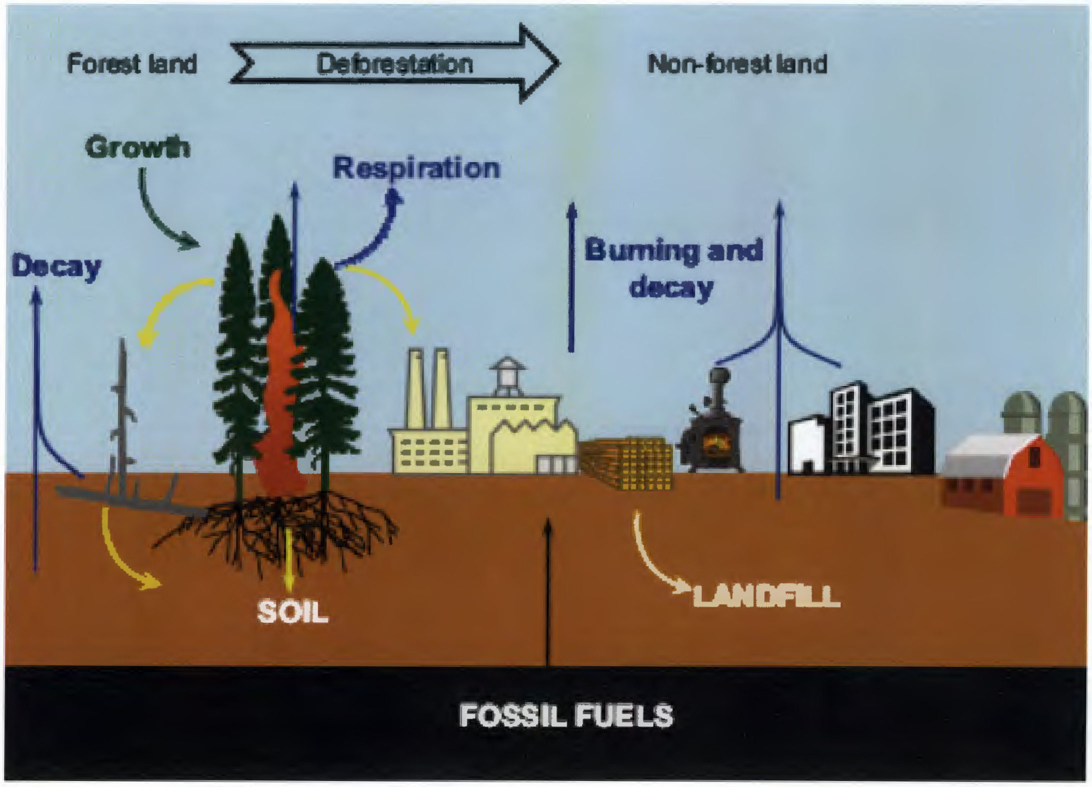
While it is a given that forestry-based projects have the potential to sequester carbon, it is unclear whether this could be profitable in current or future carbon trade markets. Strategies to move toward carbon neutrality before a compliance regime is enacted in Canada could give a company an early advantage during this transition, but are there enough incentives for first movers and what are the risks? The lack of progress from the international community has been a cause of uncertainty (Pinske 2007). As forest companies struggle through a period of record low commodity prices and currency risk on exported goods, carbon trade in this sector is a possible revenue source that has not received a lot of research interest to date.

Several forest companies are currently active in moving from heavy reliance on fossil fuels to using residual wood fibre for energy required at processing facilities. In some instances, co-generation is allowing companies to use this as a revenue source by selling excess electricity that is being produced. These "green" projects are also incented by way of tax relief or other government stimuli in some jurisdictions. In other cases, they may be credited with verified emissions reductions (VERs) that would count as emission offsets. These government incentives are part of a broader movement to create what has been called a "low carbon" or "green" economy. Where this is occurring, there is a good foundation to establishing a complete strategy that moves a company toward the future expectation of carbon neutrality and possibly other revenue sources.

As part of the answer to stabilizing atmospheric carbon levels over the next 20 to 50 years, forests have been identified as a natural way to remove and secure carbon until technology provides a more effective alternative (Sedjo 2005). Through the process of photosynthesis, carbon is removed from the air and secured in woody fiber for long periods of time. Growing trees for carbon sequestration is considered as both legitimate and crucial, although there are some risks that need to be addressed such as damage due to disease, fire, or insect. One of the barriers to forest offsets is the lack of recognition for carbon retained in harvested wood products under international rules. In reality, about 40% of timber harvested is retained within long-lived products such as lumber and panels (Dymond and Spittlehouse 2009). This lack of acceptance, particularly in compliance markets, has prevented forest carbon initiatives from becoming a major component of the worldwide carbon project portfolio to date.

Around the world, the role of forests has become center stage in climate change issues in public policy, research, and investment (Hamilton et al. 2010). In fact, forestry could be the only industry sector that may be a net carbon sink (Ximenes and Cowie 2008). This means that more gaseous carbon is removed from the atmosphere than is released to it. While healthy growing forests are usually carbon sinks, since 2002 in British Columbia (BC) forests overall have become a net source of carbon to the atmosphere (Dymond and Spittlehouse 2009). This is mainly due to the effect of the mountain pine beetle through the vast areas of dead standing timber and the resulting increased rate of harvest in recent years. Replacing dead trees with healthy growing stock is an opportunity to reverse this trend and make BC's forests a net sink sooner than would occur naturally. However this process takes time as young stands are generally carbon sources for at least 10 years until the growing biomass exceeds that which is being lost through decay in woody debris and the forest floor (Dymond and Spittlehouse 2009). Figure 1 illustrates how carbon is cycled both in forested and non-forested environments. Carbon emissions are caused by both natural and man-made processes and naturally sequestered through vegetation growth.

Figure 1. Carbon Cycles on Forested and Non-Forested Land



Source: *Forests in a Carbon-constrained World*, http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En92.htm

This paper intends to explore the strategic value of forest carbon offsets and credits to Canadian companies within the forest products industry. This will include a strategic analysis using a variety of tools, leading into a discussion of strategic alternatives. Some rudimentary modelling and financial calculations will explore whether this can lead to diversified revenue sources that increase the value of the firm including the quantification of potential profits in different future scenarios along with what risks are involved.

In examining potential projects for a forest company, the focus will not be on energy-based projects but rather projects based on forestry activities. As most large forest companies have already moved into green energy to varying degrees, this paper will explore forestry-based projects as a potential next step in developing a complete carbon strategy. The purpose of such projects could be to offset future emission reduction requirements or to sell as carbon credits on the open market. Due to a lack of a federal legislative and policy framework within Canada, project opportunities will be examined within the context of a provincial framework. With the largest forest industry in Canada, British Columbia and the Pacific Carbon Trust were chosen to look at forestry project profitability in this study. BC also happens to have progressive emissions regulations that are based on a cap and trade system.

Carbon Markets

A carbon offset is defined as, "…any kind of reduction in GHG emissions or increase in carbon storage that helps you meet your target for mitigating climate change." (Dymond and Spittlehouse 2009). The opportunity within managed forests is to remove stem carbon that is retained in long-term products and use the residual fibre to displace fossil fuels as an energy source. This serves to both lock up carbon and displace non-renewable fuels. In other words, trees remove gaseous carbon from the atmosphere and contain it as a component of the wood, which eventually may be harvested and new trees can begin the cycle again. In this way the sequestration of future crops on the site can be considered *additional* to that previous. In addition, residual products from timber processing can be used to displace energy production that would otherwise be provided by burning coal, oil, or gas.

Carbon markets are far from being mature. Following sharp growth between 2006 and 2007, these markets have held steady in value through the credit crisis and world recession. The market appears to be poised for growth once again. Some possible triggers will be collective international will, common agreement on protocols, and worldwide economic recovery. Figure 2 shows the value of transactions in several trading markets worldwide. These include the Kyoto Assigned Amount Units (AAU), New Zealand Exchange Trading System (NZ ETS), Clean Development Mechanism Afforestation/Reforestation (CDM A/R), Chicago Climate Exchange (CCX), and Over the Counter (OTC) transactions, which are those that occur outside of formally regulated markets.

Figure 2. Historical Values in the Worldwide Forest Carbon Markets

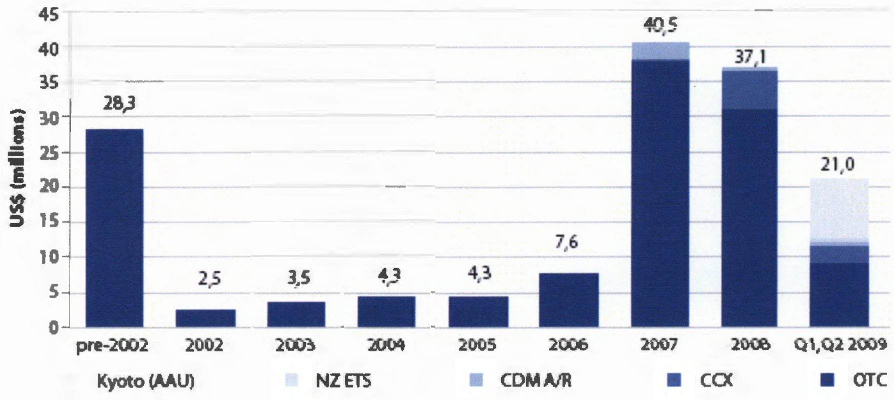


figure taken from *State of the Forest Carbon Markets 2009*, http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/SFCM.pdf

In order to consider what opportunities are available, the process of carbon trade must be clearly understood. The carbon offset market can broadly be defined as consisting of a compliance (regulated) market and a voluntary (non-regulated) market. Companies that participate in the voluntary market would typically hold environmental or social responsibilities as core values for the company. Other motivations might include investing, philanthropy, perceived marketing advantages, or building credit reserves in anticipation of a regulated carbon market.

Third party certification is becoming an important part of carbon markets. According to Ecosystem Marketplace, who collected data on 226 forestry offset projects, the use of third party standards to validate projects and verify carbon credits increased from 42% in 2002 to 96% in 2009 (Hamilton et al. 2010). One of the difficulties in tracking the market is the lack of coordination among the vast array of registries and standards that qualify as emission reductions throughout the world. The World Bank states that there are now more than 12 different certification standards that are competing for market acceptance (Capoor and Ambrosi 2009). While each of these systems are unique in some respects, the common unit of measure is carbon dioxide tonnes equivalent (t $C0_2$ e).

For land-based activities, certification standards fall broadly within 2 categories. These include those that strictly measure and monitor carbon removal and those that include qualities beyond carbon (also called "co-benefits). Among the more prominent standards for forestry offsets are the Climate Community and Biodiversity (CCB) and the Chicago Climate Exchange (CCX) (Capoor and Ambrosi 2009). Each registry has its own protocol that all projects must comply with in order to be registered. Some common components addressed by all legitimately regulated schemes are:

<u>Additionality</u> – the idea that the carbon uptake or emission reduction is incremental to regular management or "business as usual"

<u>Counted Once</u> – must not have been previously counted as an offset or credit in any other system

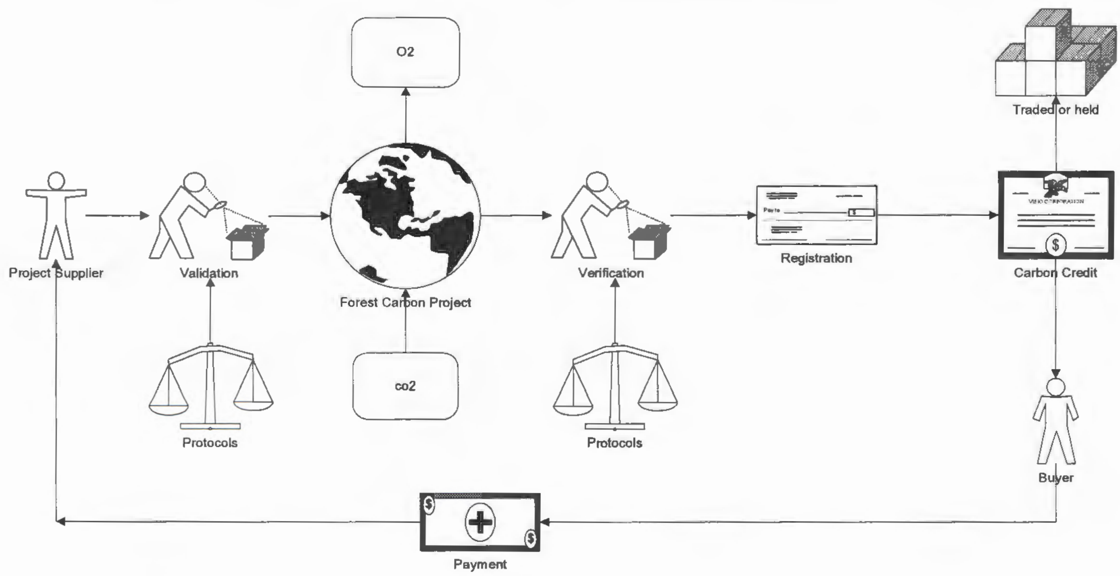
<u>Leakage</u> – having safeguards in place to prevent the loss of carbon uptake previously accounted for over a defined period of time or cause an increase in emissions somewhere else

<u>Permanence</u> – refers to the longevity and stability of the method of capture and storage

<u>Verifiable</u> – contributes to real GHG reductions, monitored and audited post-implementation

The process to achieve verified carbon credit is illustrated in Figure 3. The project proponent (supplier) begins the process by putting work up front to validate a project under a set of protocols. Then the work is carried out and verified to ensure that the credits are being correctly quantified. Once the carbon offsets are registered they may be sold or retained by the project owner. Note that this diagram is overly simplistic in that in many instances there are intermediaries between a buyer and a seller. These may include wholesalers, retailers, brokers, or market exchanges.

Figure 3. Ex post Carbon Credit Value Chain for a Forestry Project



Compliance Carbon Market

Among the compliance-based systems operating today are the New South Wales Greenhouse Gas Reduction Scheme (NSW GGAS), the New Zealand Emissions Trading

Scheme (NZ ETS), and various Kyoto Protocol driven entities such as the Clean Development Mechanism (CDM), Joint Implementation (JI), and Assigned Amount Units (AAUs). Both the CDM and JI mechanisms allow for land-based projects including forestry to count as carbon credits for which developed countries can potentially receive credit. In practice, however, a bureaucratic process and restrictive protocols have discouraged forestry projects through the various mechanisms of the Kyoto Protocol.

With the strong preference to allow market forces to control emissions, it is a reasonable assumption that Canada will eventually be operating under a regulated cap and trade system, if not under a federal umbrella then under a series of provincial schemes. There have also been indications that a cap and trade system may eventually be enacted with federal legislation, both in Canada and the United States. This belief is affirmed by the 2010 Point Carbon survey, which indicated that 61% of respondents believe that the US will have a federal cap and trade law by 2015. The American Clean Energy and Security Act (Waxman-Markey bill) and the Clean Energy, Jobs and American Power Act (Kerry-Boxer bill) are examples of cap and trade bills that have progressed to the US Senate over the past year. While neither have become law as of yet, both explicitly support land-based carbon projects (Hamilton et al. 2010). The Honourable Jim Prentice, Canada's Minister of Environment, has also suggested that North America could work under a cap and trade system and that Canada would closely follow a US model[5].

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[5] http://www.canada.com/Business/Interview+Prentice/1287646/story.html?id=1287646 accessed April 22, 2010

The European Union has been operating under cap and trade since 2005 however in North America this transition has been slower. Although movement at the federal level has been very cautious, there are a number of states and provinces that are moving forward in anticipation of cap and trade or actually initiating it. For instance, California's Air Resources Board has released draft rules for North America's first functional cap and trade system which will regulate more than 600 emitters including refineries and utilities[6]. In addition, several other states and provinces have partnered with the Western Climate Initiative which also has a goal of working under cap and trade by 2012. BC has also approved the Greenhouse Gas Reduction (Cap and Trade) Act and the Emission Offsets Regulation. As these pieces of legislation come into force there will be financial implications for companies that operate in BC based on how they manage their carbon footprint.

In terms of price, the compliance forest carbon market has held a premium over the voluntary markets with a volume-weighted price average of \$10.24/t CO_2 compared with an overall average of \$7.88/t CO_2 to date (Hamilton et al. 2010). The recent trend within compliance markets has been greater amounts transacted with lower values per tonne to keep the total market value somewhat balanced since 2007.

Voluntary Carbon Market

The voluntary carbon market world-wide has grown at a rapid pace in recent years. For example, according to the World Bank its value increased by over 50% from \$263 to

[6] http://www.vancouversun.com/story_print.html?id=2268217&sponsor= accessed April 22, 2010

$397 million USD for the years 2007 and 2008 respectively (Capoor and Ambrosi 2009). A few of the many forestry-based projects are identified as examples below:

- South Africa's Standard Bank is targeting A$250 million to manage planting and management of 50,000 ha in Australia for carbon sequestration[7].
- In October 2009, British Petroleum signed a deal with Carbon Conscious - an Australian sharefarming subsidiary - to plant up to 10 million Oil Mallee Eucalyptus trees across Australia's wheatbelt. In July of the same year BP also signed a carbon sink forest deal with Origin Energy that is potentially worth up to $169 million[8].
- Brazilian beef group J&F, ag. firm MCL, and two pension funds are also partnering to plant eucalyptus on 335,000 ha of degraded pastures. The purpose is initially to supply wood chips for power generation but they also expect to earn revenues through the sale of carbon credits[9].
- Finite Carbon announced a 4300 acre forest land project located in eastern Tennessee under the Improved Forest Management protocol under the Climate Action Reserve.[10]

Growth within Canada is also gaining momentum with numerous offsetting projects occurring across the country in a variety of industries. For example, the federal government has established a voluntary registry for domestic projects (including forestry) to issue offset credits under Canada's Offset System for Greenhouse Gases (Greig and Bull 2009). Also, designed to sell carbon credits to large businesses, the Toronto-based Greening Canada Fund was launched in October 2009 and has already received

[7] http:// www.reuters.com/article/idUSLR41915920091028 accessed April 22, 2010
[8] http://sj.farmonline.com.au/news/state/agribusiness-and-general/general/millions-poised-for-carbon-forestry-investment accessed January 10, 2010
[9] http:// www.reuters.com/article/idUSLR41915920091028 accessed April 22, 2010
[10] http://www.risk.net/energy-risk/news/1595996/forestry-project-launched-offset-protocol accessed April 22, 2010

investments from the BMO Financial Group, and the TD Bank Financial Group for amounts of $10 million and $3 million respectively[11]. Within the forest industry itself, there is a progressive movement toward carbon accounting and eventually carbon neutrality. This is demonstrated by the commitment from the Forest Products Association of Canada (FPAC) membership in October 2007 to become carbon neutral by 2015 without the use of carbon offsets[12]. Member companies essentially have less than five years to ensure that they are on track to meet this commitment.

Even outside of Canadian registries, it has become easier to sell offsets from Canadian projects internationally. In July 2008 the Voluntary Carbon Standard Association announced that it would accept voluntary carbon units (VCUs) without requiring the Canadian government to provide evidence that it would not be double counted as part of compliance with the Kyoto protocol. This decision will streamline the bureaucratic process to allow the owners of these projects to offer their offsets to a broader global audience. This could yield higher prices to the developers of these projects[13].

While the volume of trade in the voluntary market is increasing, the price has faltered. According to a survey of 141 corporate purchasers of forest carbon offsets in 2008, the average price paid was between $7 and $9 USD/t $C0_2$, although there was a wide range of prices paid depending on the perceived quality of the offset. Also there was a strong

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[11] http://www.investmentexecutive.com/client/en/News/DetailNews.asp?Id=51505&IdSection=146&cat=146 accessed April 20, 2010
[12] http://www.fpac.ca/index.php/en/carbon-neutral-pledge accessed March 15, 2010
[13] www.finacialpost.com/story-printer.html?id=2234714. accessed January 15, 2010

demand among buyers who wanted co-benefits in biodiversity and community values. Nearly all buyers were willing to pay a premium for the CCB standard offsets, but most were not willing to pay more than a \$3/t CO_2 premium. The survey also found that while there was a preference among buyers to pay for offsets only after they are delivered, there was some interest in pre-financing offset projects, particularly with North American buyers. (This "ex ante" approach to carbon sales may be of particular interest to proponents of forestry projects with long life spans.) Finally, a large number of buyers were interested in purchasing call options[14]. These are contracts that allow the buyer to purchase a specific quantity of carbon offsets, at a specific price, for a defined time period. This would suggest the expectation of future price increases.

Market Opportunities

Carbon credits, or the ability to acquire them, are truly tangible assets and should be recognized as such by accounting standards. While these assets may not be as liquid as cash or other commonly exchanged assets, they are certainly more marketable than traditional long-term assets such as property, plant, and equipment. In holding these credits as current assets, they could either be bought and sold timing market cycles or held as a reserve for a time where cash is required in the future. An example of the value recognition is after the worldwide recession began in late 2008 and during the subsequent credit crisis, there was a massive selloff of carbon permits from European companies that

14 http://www.ecosecurities.com/Standalone/Forest_Carbon_Offsetting_Trends_Survey_2009/default.aspx#19721. accessed April 22, 2010

was mostly on the spot market. There were also many call options placed in order to hedge against compliance exposure (Capoor and Ambrosi 2009).

The real potential here is that since carbon trade appears to be in a growth phase there is potential for significant value appreciation. Knowing that regional governments such as BC and California have committed to working toward a low carbon future, demand in the carbon market should continue to increase. An important question to answer is how responsive the supply will be to meet this demand and from what industry sectors the demand will be supplied. Part of the answer rests in the amount of private investment that is given to carbon projects now and in the future. Jennifer Weiss, spokesperson for California's Climate Action Reserve suggests, "Considering the popularity, industry interest and high offset prices, we expect to see continued growth in forestry projects not just in the US but throughout North America".[15]

As mentioned previously, BC has established a legislated framework with the intention of encouraging the use of renewable energy sources and to enable a provincial carbon market. The public sector is leading the way in this venture with a commitment to carbon neutrality in 2010.

Pacific Carbon Trust

Within BC, the Pacific Carbon Trust (PCT) is a Crown corporation that was established in 2008 with the stated purpose of providing high quality offsets from projects initiated in BC. The primary client is initially the Province of BC to meet their carbon neutral

[15] http://www.risk.net/energy-risk/news/1595996/forestry-project-launched-offset-protocol accessed April 22, 2010

commitment. As of June 30, 2009, the BC Government had retired 34,370.44 tonnes of carbon, purchased from 15 different projects. This refers to purchased offset tonnes that may not be transferred or resold.

Their process follows the BC Emissions Offset Regulation which begins with project verification and then registration. While there currently is no registry in BC, a BC project can be registered in an outside jurisdiction. Once a project has moved through the verification and registration stage it is then marketable. The PCT currently has a draft protocol for forestry projects which includes fertilization, select seed, and afforestation as means to sequester carbon. The purpose of this protocol is to provide guidance and support for offset projects that can be retired by the PCT. These initial three categories were chosen because baselines and additionality are easier to define and quantification protocols are further developed. Another advantage is that these types of projects do not have complex issues that present concerns with leakage. Several other forestry related protocols are being considered for the future (Raymer, 2009).

The PCT negotiates prices with offset suppliers and these contracts are not published. The offset value is determined based on both market pricing and offset quality for the verified project. These offsets are then sold to government at \$25/t $C0_2$. The private sector within BC is also encouraged to purchase offsets from the PCT and some have already made purchases. Table 1 shows a typical weekly view of carbon prices as gathered from markets around the world. Information such as this factor into the pricing negotiations between the PCT and project proponents.

Table 1. Carbon Market Pricing

Carbon market snapshot
March, week 1

INSTRUMENT	PRICE	MTH CHG
EUA Dec10 EUETS Phase II	**€13.30**	+0.58
EUA Dec13 EUETS Phase III	**€15.56**	+0.27
CER Dec10 EU secondary	**€11.86**	+0.70
CER erpas Primary CDM	**€7.7-10.4**	-
RGGI Dec 10 US RGGI allowances	**$2.13**	+0.02
CRT Dec 10 V09 CAR VERs	**$5.25**	-2.00
CFI 2010 CCX VERs	**$0.07**	-0.03

Exchange traded prices only.
€=euros $=US dollars
Sources: Reuters Interactive, ECX, CCX, Nymex, IDEAcarbon

List of Acronyms:

EUA – European Union Allowance

CER – Certified Emission Reduction

RGGI – Regional Greenhouse Gas Initiative

CRT – Carbon Reduction Ton

CFI – Carbon Financial Instrument

ECX – European Climate Exchange

CCX – Chicago Climate Exchange

Nymex – New York Mercantile Exchange

Methodology

First Mover Advantages

A firm may benefit in various ways by taking the initiative to become a "first mover". A common occurrence among first movers is that they have significant influence in the development of government legislation and policy. Since the regulatory environment for carbon trade is still in developing in Canada, this could be an opportunity through market leadership. A company might also gain an economic advantage by reducing their emissions prior to a cap and trade system becoming established. This could effectively put the firm in a position to be a "seller" while their competitors are "buyers" in order to meet emissions targets. Another benefit that this may provide is a comparative advantage in marketing and sales of forest products. For example, the first "carbon-neutral" forest company could leverage this accomplishment by promoting their brand publically. This could lead to a favourable response from customers. Finally, another characteristic of first movers is that they can easily acquire the best of limited resources by not having to compete for them. This could be manifested through land acquisition for forestry projects, or by securing contracts with the government for forestry projects on Crown Land.

It may be said that a company that is developing a low carbon strategy will promote the firm as being socially responsible. The trends of companies moving to corporate social responsibility (CSR) have been attributed to various strategic factors. Some have attempted to justify this behaviour by suggesting that companies that are leaders in CSR outperform peer companies in stock price performance. Others argue that competitive advantage is achieved by gains in reputation and or public acceptance. The point is that the popularity of CSR is not only attributed to business ethics but also to competitive strategy (Peterson et al. 2005). This becomes particularly apparent when a "stakeholder" view is considered rather than simply a "shareholder" view. Table 2 illustrates what a stakeholder summary might look like for a public forest products company in Canada.

Table 2. Stakeholder Summary for a Public Forest Products Company

Stakeholder	Interest	Influence/Power
Shareholders (represented by Board of Directors)	- maximize value of the firm - (Ethical interests)	- provide direction for management on major decisions such as policy and strategy
Customers	- reliable delivery, consistent quality, low cost - Ethical interests	- ability to impact revenues based on choice - demand impacts production and/or price - can pressure supplier to provide assurances that are not related to the product based on ethical interests (e.g. Certification)
Creditors	- minimize risk of default - (Ethical interests)	- covenants on debt can limit management flexibility - convertible debt can give shareholder power
Employees	- jobs, fair working conditions - personal agreement with job and company direction	- limited influence as individuals - significant influence collectively
Government	- minimize risk of default (stumpage and other revenues) - environmental performance	- collect a well defined series of revenues - can penalize for environmental offences
Local Community	- employment - minimize risk of default (stumpage, taxes, and donations) - environmental performance and ethical interests	- limited influence on the surface - more influence considering that membership comprises a component of all other stakeholders - some influential segments (e.g. Chamber of Commerce)

Stakeholder Analysis

The primary stakeholder for a public company should be its owners or shareholders. For shareholders the primary objective must be return on investment, either through dividends or capital appreciation, or both. However an interesting trend that has occurred more recently is the popularity of "ethical investing". It may be that some investors are willing to forego some level of profit for the assurance that companies within their ownership are operating in a socially acceptable or ethical manner. It is difficult to determine to what extent this would be true of individual and institutional investors in Canadian forest companies.

An important question, based on stakeholder analysis, is whether a public company should move toward carbon neutrality before receiving a legal mandate. The considerations include the potential impacts to shareholders, creditors, customers, and employees. While climate change action is likely not the primary concern of any single group of stakeholders it is very likely that it is either a secondary or tertiary concern to all. Therefore it would be in the best interest of the firm to address this in some manner.

Peterson et al. (2005) suggests that among all the various stakeholders that influence managerial decision-making, regulators are highlighted as the most effective. This is true particularly where there are trade-offs between profits and protection of the environment. As reporting requirements and codes of conduct become regulated, there will be a requirement for companies to comply. Currently, rather than forcing companies to begin their green transformation, the present government tactic is to allow market incentives to motivate companies to change.

To reduce uncertainty, many companies will rely on being imitators and others will adopt climate change initiatives as a group. For example, as mentioned previously, FPAC has been moving the larger industry along the journey to a low carbon future. The decision to be made by individual companies is whether or not a first mover strategy would lead to profitable opportunities that present a competitive advantage. If this strategy were successful, it could only be sustained if they continue to redefine themselves as a low carbon leader with bold, new initiatives. Due to the imitation factor, a successful carbon strategy will soon lose its competitive advantage if it is not continually evolving.

To initiate a low-carbon culture within an organization, a logical first step for an early mover would be a focussed effort on reducing their emissions or "carbon footprint". The impacts of simple things like recycling programs or energy use in buildings are relatively easy ways to get people on board before instituting bigger changes in the future. Through sourcing ideas with staff involvement, there will undoubtedly be innovative options to reduce GHG emissions in the company. Considering the concept "what is measured can be managed", the starting point would be to define the current carbon footprint for the company as a baseline. Knowing this baseline will allow the company to set visible goals in reducing the carbon impacts of their business. This can be a win-win both from a cost reduction and an employee engagement perspective. An additional upside is the potential to create a trading surplus of carbon credits which could in effect make the company a seller rather than a buyer in a future cap and trade system, thereby creating a competitive advantage among its peers.

Environmental Scan (PEST Analysis)

Before beginning to formulate strategy, a company must scan the external environment to identify external factors that can be exploited. Research has shown a positive correlation between environmental scanning and profits (Hunger and Wheelen 2007). The PEST analysis is done by simply detecting and analyzing the major forces that are at play mainly outside the company's industry. These forces can be broken into four categories: Political-legal, Economic, Societal, and Technological (Appendix I).

Political-Legal Forces

Within western Canada, the political-legal situation has also been changing with respect to climate change. In an effort to drive changes at home, the BC government passed the *Greenhouse Gas Reduction Targets Act* in 2007 and the *Greenhouse Gas Reduction Act* in 2008. The Reporting Regulations under the latter was enacted as of January 1, 2010 requiring emitters of over 10,000 tonnes of greenhouse gases to report their emissions[16]. At the same time there have been efforts to move to a low-carbon economy by using market forces. Evidence is seen with voluntary actions and commitments such as combining with the Western Climate Initiative (WCI) and instituting a mandate and mechanism by which all government agencies are to become carbon neutral. As mentioned previously, the PCT was established to make local carbon offsets in BC available to meet this goal.

Considering the various standards available, a proponent of a forestry project must consider which protocol would look most favourably on their project. In general, forestry projects have not been a primary focus of many schemes and therefore several protocols are either new or still under development. Having a clear understanding of the rules and how they are applied is critical to a project's success. Also important is the stability over time of these protocols. Forestry projects are long in duration by their very nature and typically will not yield immediate carbon storage results. Therefore a serious risk is that standards may change over time due to new science or political agendas. These are important risks to consider prior to investment.

Economic Forces

The forest industry worldwide has suffered through one of the worst ever economic downturns. Following one of the deepest and longest troughs in commodity price cycles from 2005 to 2008, the worldwide recession struck in the late 2008 which continues impact business of all sorts. One of the ways that federal governments have attempted to stimulate economic growth is by using debt to create vast amounts of "stimulus" money available to encourage economic growth through retail spending and investing. An effect of the economic recession is monetary and other policy incentives that promote the renewable energy industry which is viewed as a necessary transition to reduce dependency on fossil fuels over the long term. For example, the Canadian Government has committed $1.5 billion to encourage the forest industry to diversify into green

[16] www.env.gov.bc.ca/epd/codes/ggrcta/reporting-reg.htm accessed April 23, 2010

energy[17]. Another recent trend on the world scene has been the economic rise of the BRIC nations. These four developing countries - Brazil, Russia, India, and China – have all experienced economic growth and prosperity that has increased the individual standard of living in these regions and this growth is expected to continue[18]. This has implications for the west, not the least of which will be an increased burden on global resources, including energy.

In the European Union Greenhouse Gas Emission Trading System (EU ETS), the 2008 reporting showed that emissions were reduced overall by approximately 4.6% but was still short of the overall target. This reduction is predicted to be 30% due to cap and trade, 40% due to recession, and 30% due to energy conversion (World Bank, 2009, 7).

Societal Forces

According to a Globescan survey conducted in late 2009 for the BBC World Service, 64% of people think that climate change is a "very serious" problem, up from 44% in 1998. According to Globescan chairman Doug Miller, "The poll shows strong worldwide support for action on climate change, in spite of the recession."[19].

While the world is composed of a diverse mosaic of societal interests, environmental consciousness is one trend that can be identified. Based on the behavior of democratic

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[17] http://www.trurodaily.com/Business/Natural-resources/2010-02-02/article-822235/Forestry-industry-must-diversify,-capitalize-on-demand-for-green-energy:-study/1 accessed April 23, 2010

[18] http://www.thaindian.com/newsportal/world-news/global-financial-power-to-shift-to-bric-economic-forecast_100133875.html accessed April 23, 2010

[19] http://www.mundgroup.com/archivos/Series_9_Number_41_MUND_GlobeScan_BBC_Climate_Change_in_Public_Opinon.pdf accessed April 23, 2010

nations, it can be argued that climate change consciousness is strong within Europe, with growing concern from all other jurisdictions as demonstrated by the regulatory and incentive-based actions of these governments. At COP 15, one common theme was the tension between developing countries not wanting to be economically constrained by emission reductions and the unwillingness of developed nations to fund the transformation to a "green economy" in these countries.

Technological Forces

In most industries, technology continues to drive change rapidly. Since the rise of the internet and continued advances in wireless communication our society has become increasingly dependant on technology in our daily lives.

During the recent period of rapid technological advances, there has not been an abundance of technological changes in the forest industry. Research and development has largely been a function of pooled industry/government-funded resources (e.g. Forest Engineering Research Institute of Canada - FERIC) rather than investment from individual firms in the forest sector. The focus of technology has been to increase the efficiency and production of manufacturing facilities, which in BC are generally considered world class.

TOWS Analysis

A TOWS analysis is a helpful tool to examine the competitive landscape for a forest products firm exploring carbon strategies (Appendix II). This tool is a variation of the more common SWOT analysis and explores how the **T**hreats, **O**pportunities, **W**eaknesses, and **S**trengths of the firm interrelate with each other and lead to potential strategies that can be further evaluated. Drawn as a table, this chart surveys both dynamics within the company and the competitive landscape outside of the company. This gives an indication of where the inherent competitive advantages lie both for a forest company in the larger carbon market and as an early mover within the forest sector. This exercise also examines the characteristics, capabilities, and market position of a firm that can be successful with a carbon strategy. The result is a visual display of where a forest company can leverage its strengths within the broader carbon market.

External Threats

One of the threats to pursuing a carbon strategy is the prospect, however remote, that the commonly accepted theory of global warming is in fact proven false with no risks to current or projected future emission levels. There has always been a portion of the scientific community that has not been convinced that the planet is becoming harmfully warmer. Recently this movement has gained momentum as emails from IPCC scientists were recovered that suggested data tampering has occurred in previous studies[20]. These serious allegations have had international experts calling for an explanation to these claims including distinguished Canadian scientist Andrew Weaver calling for the resignation of the IPCC chair[21]. While this specific matter remains to be resolved, the general conclusion that the earth is warming has been reached by many different studies.

[20] http://online.wsj.com/article/SB10001424052748703630404575053781465774008.html accessed April 23, 2010
[21] http://www.nationalpost.com/todays-paper/story.html?id=2507120 accessed April 23, 2010

Much critical thought has been put into this question and a general consensus has been reached. Considering this, the chance that global warming is not occurring is likely remote.

Assuming that climate change is occurring, other threats would include whether a forest company would have the financial means to become a carbon player in a meaningful way. As the forest industry worldwide is reeling from economic pressures, the survivors are not showing strong balance sheets, compared to companies in the energy sector for example. Also, one would have to consider the inability to achieve international agreement on climate change mitigation as a threat to any company's carbon strategy. The recent Copenhagen conference is testimony to how difficult it will be to reach consensus, which could be an easy way for non-performing nations to opt out of any meaningful commitments and undermine a collective process.

External Opportunities

It appears that several opportunities are on the horizon. The first is the fact that the carbon market is young which indicates that the steep growth in both projects being developed and carbon traded will continue for some time yet. This growth would only be enhanced by a regulated cap and trade scheme in North America and in other global regions. The belief that this growth will occur is supported by the current interest of buyers in the carbon futures market and the desire to purchase call options as noted earlier.

Another opportunity can be in branding and marketing for forest companies and their products. As the public seems to be ever more aware of the climate change concern and more demanding of companies that produce consumer goods, it is reasonable to expect the standards for climate action to increase. This trend has been seen through the past 20 years with sustainability concerns in forest practices which eventually led to wide scale third party certification throughout the Canadian Industry. With 145.7 million hectares of land under third party certification, Canada now has 40% of the world's certified forests[22]. Much of this change was driven by the expectations of customers or retailers. For example, home building center RONA has committed to only selling third party certified wood products by the end of 2010 with at least 25% being Forest Stewardship Council certified by the end of 2012[23]. Given this progression in the relationship between customers and suppliers, how long will it be before the powerful retailers of forest products demand carbon neutrality from producers?

As discussed previously, the province of British Columbia has made a concerted effort to be a leader in the low carbon economy and is actively seeking to purchase carbon offsets from verified private sector projects. Meanwhile the acceptable list of forestry projects seems to be expanding within many protocols. As it was recognized that land based offsets are an important part of lowering greenhouse gas levels, and that the Kyoto Protocol has not attracted sufficient investment, there is a movement to encourage and

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[22] http://www.fpac.ca/index.php/en/sustainable-solutions accessed April 23, 2010
[23] http://www.rona.ca/content/november-21-2008--rona-unveils-its-wood-products-procurement-policy_2008_press-releases_investor-relations accessed April 23, 2010

expand these types of offsets. Within BC for instance, the PCT has the objective to expand it's forest offset protocol once the initial protocol is established (Raymer, 2009).

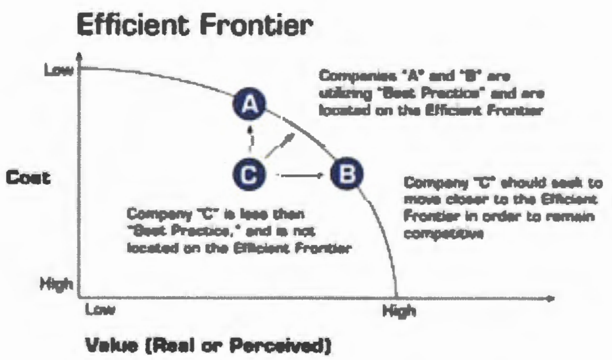
Internal Weaknesses

One of the drawbacks for Canadian forest companies, particularly in the west, is the lack of private land ownership. As the vast majority of their operations occur on Crown land under various forms of tenure, the assurance of benefit from long term carbon sequestering activities are uncertain at best. Even if the rights and assurances were granted, Canadian forests are also at an investment disadvantage due to short growing seasons. This limits the amount of $C0_2$ that may be captured compared to other countries on a per dollar of investment basis. Another weakness is that there is a notable lack of expertise of carbon trade within the industry including amongst many of the consultants that support the industry. Finally, with most or all Canadian forest companies having tight budgets and scrutinized cash flows, there may be limited options for financing new investments in forestry projects. This resourcing challenge cannot be understated. By contrast, companies from the finance and energy sectors, likely through their own retained earnings, are financing several forestry projects being conducted throughout the world.

Internal Strengths

Inherent to the strengths of forest companies is that they carry the well-earned experience and expertise in silviculture operations. This not only includes manpower but also key assets such as seed orchards and nurseries. These skill sets and vertical integration have occurred over many years and could not be quickly replicated. Another strength is sustainable practices. This gives the advantage of both being well-versed in various protocols for third party certification but also affords the benefit of reputation in the marketplace. Operational efficiencies round out the list of strengths carried by Canadian forest companies. While there has not been a lot of strategic diversification in the industry (outside of sales and marketing), there has been a tremendous movement in lowering costs and improved utilization that has occurred in recent years. Economist and strategy guru Michael Porter would describe this as approaching the "efficient frontier" which has been required through fierce competition in the industry. This competition has led to an industry that is lean and efficient.

Figure 4. Efficient Frontier



Adapted from Michael Porter, "What Is Strategy?" Harvard Business Review, November-December 1996.

Strategic Alternatives

In order for a company to effectively implement strategy, it must make a conscious decision of what it must give up. This concept of trade-offs is an important consideration because without it the firm is in danger of straddling which tends to make both the company's core business and new business less effective and easily imitated by competitors. According to Porter (2008, p70), "Strategy is making trade-offs in competing. The essence of strategy is choosing what not to do." In considering a carbon strategy, a forest products company must therefore think about what it is willing to give up in terms of trade-offs. The Canadian forest industry has been forced to reduce its cost structure and create operational efficiencies over the past several years. When operating toward the outer edge of the "efficient frontier", gains in one area will come at a cost to another. Companies that have survived the recent economic downturn are now operating closer than ever to this theoretical threshold in producing forest products. However it may be argued that they have not done well to lessen competitive forces through product diversification or developing niche markets.

It remains unclear as to whether direct investment in forestry carbon can be a profitable venture at today's prices. Nonetheless various projects are being initiated in Canada, most notably in afforestation. Further to this idea, Stavins (1999) notes that the marginal costs (opportunity costs) on higher quality agricultural lands sharply increase when considered for afforestation use. Tropical deforested regions have been considered to be more efficient carbon storage engines and generally offer lower opportunity costs for the land than many temperate regions (Newell and Stavins, 2000). However, a recent study has found that cool, moist, temperate forests provide the optimal carbon storage potential of any global forest region (Heather et al. 2009).

Hoffman (2008) suggests that it is critical for a company to know their price for carbon prior to a regulated environment in order to form an intelligent strategy. He also recommends that companies use benchmarking. This is the done by comparing your company's processes and practices to the best companies within and outside your industry, through direct observation. This is a way of learning from others' successes.

Industry First Movers

Despite North American forest product companies being largely unprofitable for some time, there are indications that forest companies are beginning to consider their role in climate change. For instance Weyerhauser recently announced that they have reduced their carbon footprint by 10% from the year 2000.[24] As a company, they have committed to reducing their carbon emissions by 40% from 2000 levels by the year 2020. Their stated primary method to achieve this goal is by deriving more of their energy requirements from carbon neutral biomass. This proposal is expected to benefit shareholders through lower energy costs. Thus the company has began the process of measuring their carbon footprint through energy use at processing facilities and the emissions given by their transportation fleet. In measuring their carbon footprint, Weyerhaueser uses the Greenhouse Gas Protocol Initiative's Greenhouse Gas Protocol,

[24] http://www.greenbiz.com/news/2009/07/31/weyerhaeuser-cuts-ghg-emissions-takes-steps-reduce-energy-water-use accessed April 23, 2010

Revised Edition[25]. Their carbon accounting process through this protocol normalizes the baseline to consider the effect of acquisitions and divestures. In this way emissions reductions are not understated or exaggerated as a result of the selling and buying of company assets. While they have not yet recanted their 40% reduction pledge, they are now stating that the target may have to be revisited because of the economic downturn and the capital required to make the switch to bio-energy on a large scale.[26] On March 18, 2010, the company announced that it would become the twenty-ninth member of the U.S. Climate Action Partnership group which is lobbying coalition of companies and NGOs that are promoting federal climate and energy legislation in the United States.[27]

AbitibiBowater has also chosen to proactively go down the path toward a low emissions future. Ranked the leading forest products company in the 2008 Climate Disclosure Leadership Index, they were determined to be best-in-class in disclosure practices and emissions reporting. Several initiatives have helped this company to reduce absolute emissions 51% from 1990 levels. President and CEO David J. Patterson declares, "We are committed to reducing our carbon footprint and we want to become a carbon-neutral enterprise".[28] Other companies may be undertaking similar initiatives but not disclosing them publically.

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[25] http://www.ghgprotocol.org/standards/project-protocol accessed April 23, 2010
[26] http://www.weyerhaeuser.com/Sustainability/Footprint/ClimateChange accessed April 23, 2010
[27] http://www.nytimes.com/gwire/2010/03/18/18greenwire-weyerhauser-joins-enviro-industry-climate-coal-31853.html accessed April 23, 2010
[28] www.americanprinter.com January 2009-Industry News

Potential Projects in British Columbia

The quantification framework for calculating forestry offsets in BC is summarized within the Emission Offsets Regulation. The regulation also requires that biological projects store carbon for the equivalent of 100 years or more and that payment is "ex post" which means after the offset is generated. Removals are calculated differently for projects that involve future harvest than those that do not (Raymer 2009). Currently the forestry offset protocols do not recognize the capture and storage of carbon within products in use. This has deterred investment in forestry projects. The problem of assessing carbon stored in manufactured wood products seems difficult when one thinks of all the different possible uses of the same product, especially lumber and panels. The other problem is that rarely will these products be in service for 100 years. However, by tracking product use, values can be assigned based on averages. For instance, a high proportion on sawn wood has a service life of 50 years, after which much ends up in landfills where at least 80% of the carbon remains after 46 years (Ximenes and Cowie 2008)

Land ownership or control is another important issue. Unless the land is owned or a legal transfer of rights is in place, any benefits by way of carbon offsets would not be realized. In Canada, this would mean either fee simple ownership, a long-term lease arrangement, or a long-term contract that secured control of the land base for the period in question. Since the majority of forest land is owned by the Crown, this becomes an obstacle for private investment.

Other important considerations for each alternative is local climate and site index. Within BC, there is much diversity in climate and site productivity. Other factors to consider are the rate of decay releasing carbon from debris, forest floor, and soil. These factors can also vary considerably based on site.

Afforestation

Afforestation refers to the process of converting denuded land to forested land. For example, stocking agricultural land with trees would be considered under this definition. The best opportunities here would appear to be with land that is both inexpensive and devoid of any requirement for site preparation. Inexpensive agricultural or range land in rural areas and is marginal in terms of farmland would be well suited. This land would also have to fall under for "change of use" status to be available for afforestation. Any potential benefits would be reduced by the need to undertake any form of physical treatment such as slash burning, brushing, mounding, or trenching. Not only would these activities incur immediate expense but they would also be an immediate source of carbon emissions through combustion, removing vegetation, and exposing soil. This could delay the time for the site to become a net carbon sink by as much as 30 years (Dymond and Spittlehouse 2009).

Fertilization

Fertilization projects have the opportunity to increase carbon uptake in forest stands by increasing the mean annual increment (growth rate) of the stand. These increases are for a finite period of time, not continuous or exponential. The amount of potential enhancement varies according to tree species and site index. The incremental growth is what can be claimed as additional carbon capture.

The operational method to apply fertilizer to a forest stand uses aerial methods with a fixed wing aircraft or helicopter. While several projects have been conducted throughout the province for research or stand improvement that is funded publically, fertilization is not a common treatment method on Crown Land in BC. Through the various research projects conducted over time, there have been yield tables established to show how this treatment impacts growth of different tree species on various sites across the province.

Select Seed

Select seed projects are those that use planted seedlings selected for specific traits such as increased growth rate, volume, carbon content, or disease and pest resistance. These seeds may be from natural sources with superior provenance or from a seed orchard. In demonstrating additionality, the baseline condition would be one where select seed is not used or where an increased proportion is used from common historical practice.
In this study, the projected genetic gain used in scenarios 3 and 6 is 10% at 60 years.

Eligibility Criteria

The "British Columbia Forest Offset Protocol"[29] was published as a draft for review on June 24, 2009. A final protocol is expected to be released soon. For the purposes of this study, the draft protocol will be used to examine eligibility and is summarized as follows:

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[29] http://www.for.gov.bc.ca/mof/climate_change/BCForestOffsetProtocol_DraftJune24th.pdf accessed April 23, 2010

Quantification of Project Reductions

In order to show how the results will be achieved, it must be tabled and graphed to demonstrate the amount claimed. Two methods are available under this section. The first is to grow trees with no harvest planned within 100years, the second is to harvest within 100 years. This project will explore base case harvest scenarios at 60 and 100 years after planting, base cases with fertilization, and base cases with fertilization and select seed treatments applied.

Permanence

Risk is inherent with any forestry project or activity. Loss as a result of wildfire, insects, pathogens, or drought can all be detrimental to the permanence of a project and are called risk of reversals. The Emission Offsets Regulation of BC[30] requires that risk mitigation and a contingency plan must be in place to demonstrate due diligence should a reversal occur. Some approaches that have been accepted in other protocols are:

1) to apply a discount factor to the amount of C stored
2) to establish a buffer pool, or
3) reversal replacement.

Within this project, a 10% discount factor was applied to the incremental carbon claimed which could be an acceptable way to address risk of reversal.

[30] http://www.pacificcarbontrust.com/LinkClick.aspx?fileticket=r%2BIAy2pzzxY%3D&tabid=90 accessed April 23, 2010

Leakage

The protocol currently recognizes the potential for unanticipated decreases or increases of GHGs, caused by the project, realized outside of the project boundaries. The protocol describes how government can address these concerns but offers no specific guidance to proponents at the project plan stage.

Inventory and Monitoring

Established procedures in the forest industry should be used by proponents to collect tree stocking and growth information. This would include silviculture surveys and change monitoring inventory using vegetation resource inventory standards. A monitoring document must be submitted as part of the project report. Finally, all plans and associated data must be made publicly available as per the Emission Offsets Regulation.

Third Party Assurance

The project plan must be *validated* to ensure that the plan meets all the eligibility criteria. Similarly, the emission reductions or removals must be *verified* through the periodic project reports. These are quality assurance steps that must be conducted by a third party and signed off by a professional.

Modelling

Models are an acceptable means to quantify the baseline and incremental carbon stocks as they relate to a project. If the model is accepted by the protocol and a field study has verified the existing site conditions and other assumptions, then the project proponent is able to proceed with the project on the basis of model simulation. As monitoring occurs over time, the proponent is able to correctly set the parameters in the model. There are a variety of carbon models available and they all function to determine existing carbon stocks on a site and predict the effects of forest management activities. The workings of the model is based on field study data showing relationships between measureable tree growth and carbon that is stored, both above and below ground. Also the relationships with site types and stand history give an indication of the carbon that is captured within the soil. Both the TIPSY and CBM-CFS3 (see below) are stated to be pre-approved for use in the aforementioned draft protocol.

Analysis Tools

Carbon Budget Model - CFS3

The model used for this analysis is CBM-CFS3[31] which is an aspatial, stand and landscape-level model used to simulate the dynamics of a variety of forest carbon stocks (aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon). It is also compliant with the carbon estimation methods set forth by the IPCC.

It should be noted that all models have their own set of shortcomings that must be recognized. For the CBM model it has been noted that yield tables for BC have been overstating the true carbon yields on a number of sites. The means of correction suggested by Natural Resources Canada is to use net merchantable volume yield curves rather than those for gross volume (Kull 2010). Another concern with this model is that carbon flux estimates from the model can have an uncertainty of at least 20%. Despite these flaws, this model was chosen for this analysis since of the Canadian models available, the CBM appears to be the most widely recognized and has an intensive support mechanism that is consistently updating and improving the model's results. With respect to the CBM's shortcomings, it is often better to know where the deficiencies are and be able to compensate for them than to naively accept the results from other untested models without knowing their validity.

TIPSY

The Tree Interpolation Program for Stand Yields (TIPSY)[32] is a growth and yield program that produces stand yield tables and economic outputs created by two other models (TASS and SYLVER). It's various versions have been in use since 1985 when it was developed for forest researchers. The outputs from TIPSY that were used in this exercise were yield tables and economic analysis based on a series of selected inputs and default values assigned in the program.[33] These inputs were intentionally kept simple for this hypothetical example. These inputs also provide optimistic scenarios by design for the purpose of determining if any of the results would create an attractive case for investment. For example TIPSY default costs for site preparation, tree planting, harvesting, milling, overhead, and lumber prices were all factored into the NPV output.

[31] http://carbon.cfs.nrcan.gc.ca/CBM-CFS3_e.html accessed April 23, 2010
[32] http://www.for.gov.bc.ca/hre/gymodels/tipsy/model.htm accessed April 23, 2010
[33] J.S. Thrower and Associates Ltd. 1994. Revised height-age curves for lodgepole pine and interior spruce in British Columbia. Report to the Res. Br., B.C. Min. For., Victoria, B.C. 27 p.

Other assigned variables used in this analysis were:

- Prince George, Sub-Boreal Spruce Biogeoclimatic zone
- 5% ground slope
- 100% Lodgepole Pine planted
- 1600 stems per hectare planted
- no real cost increases
- no operational adjustment factors

Afforestation Project Description

This exercise is being done as a “pre-screening” to acquire rough estimates on profitability and therefore the analysis is intentionally being kept simple. One of the requirements for developing an afforestation project with the CBM is to have yield tables for species and site in question. These tables were developed from the TIPSY model (Appendix III) and put into the CBM model for simulation.

In this analysis, two harvesting scenarios are examined. Both scenarios are situations where deforested land is planted to lodgepole pine at 1600 stems per hectare and eventually harvested. Lodgepole pine was the species chosen due to its versatility as a pioneer species and its ability to capture carbon faster than other species such as spruce or douglas-fir. Fertilizer treatments were applied earlier than what is typical for analysis timber objectives only. A stand age of 25 years is the TIPSY default for fertilization and was thought to be appropriate to allow the stand to sequester carbon faster and thereby limit some of the time risk in the project. The site chosen was one in the Prince George area with a site index of 20[34] (a relatively good site). A summary of the six different scenarios is given below.

Scenario 1 – No treatments, harvest at 100 years

Scenario 2 – Fertilization at 25 years, harvest at 100 years

Scenario 3 – Select seed used, fertilization at 25 years, harvest at 100 years

Scenario 4 – No treatments, harvest at 60 years

Scenario 5 – Fertilization at 25 years, harvest at 60 years

Scenario 6 – Select seed used, fertilization at 25 years, harvest at 60 years

Assumptions

The model runs were done using generic assumptions with respect to the growing site conditions and disturbance pattern over a 100 year period. A summary of these assumptions are:

- Trees grown on previously deforested land.
- To mimic a project at a reasonable operational scale, 1500 ha total comprised of 3 x 500ha areas, each with low residue and average, minimum, and maximum soil organic carbon respectively
- Yield tables were generated using TIPSY model for above ground biomass using "net merchantable volume" for growth yield.
- Results for net carbon sequestered were analyzed on a per-hectare basis.

[34] Site index is a measure of site productivity for a given tree species. For example, SI 20 indicates that the trees will on average be 20m tall at 50 years of age.

Financial Analysis

Each of the six scenarios are evaluated using a financial analysis with a spreadsheet. The variables observed in the analysis are discount rate (%) and carbon price per tonne ($/t C). The exercise is done for project screening purposes to see what conditions would be necessary to make an afforestation project a good investment in the BC interior including land purchase price. It will also give an indication of the relative value of the treatments of using select seed and fertilization on that site. The evaluation is based on net present value (NPV) which is the current value of future cash flows with a given discount (interest) rate. The tests are that the NPV would have to be positive and, at a minimum, must be sufficient to cover the initial land cost. As afforestation is within a forest company's skill set, the assumption will be that if this test is met, then direct investment in forest carbon projects could be considered as part of a company's carbon strategy for financial purposes. Table 3 shows the results of the financial analysis.

<u>Other Assumptions</u>

Discount Rate - For this exercise, rates of 3%, 5%, and 8% are calculated to show sensitivity and to cover a number of possible futures and expected returns. While rates of 3% to 5% have traditionally been used for forestry projects, 8% may be a more appropriate assumption for private sector investment that includes a risk premium.

Carbon Price – Carbon price is another uncertain area in the financial analysis. With Table 1 showing a list of current pricing, it is difficult to predict what prices will yield into the future. The chosen scenarios, priced in real terms at $5, $10, or $20/t C, which would cover a range of $18.35 to $73.40/t CO_2 equivalent.

Setup Costs – Initial and ongoing costs such as third party validation and verification are not considered in this screening analysis. These are highly variable costs and their exclusion supports the evaluation of an optimal scenario.

Table 3. Summary Analysis – Carbon Afforestation Projects

		Carbon price ($/t C)	NPV @ Discount rate		
			3%	5%	8%
Harvest at 100 years	scenario 1 no treatment	$5	($340)	($413)	($455)
		$10	($165)	($321)	($420)
		$20	$183	($139)	($351)
	scenario 2 fertilization	$5	($276)	($406)	($486)
		$10	$32	($240)	($417)
		$20	$646	$91	($279)
	scenario 3 fert + SS	$5	($174)	($332)	($435)
		$10	$208	($118)	($340)
		$20	$973	$309	($150)
Harvest at 60 years	scenario 4 no treatment	$5	$450	$412	$361
		$10	$572	$503	$410
		$20	$818	$684	$508
	scenario 5 fertilization	$5	$546	$483	$410
		$10	$727	$607	$472
		$20	$1,089	$857	$595
	scenario 6 fert + SS	$5	$579	$508	$426
		$10	$793	$658	$504
		$20	$1,221	$958	$660

Discussion

The results of this analysis shows some valuable information. Based on the inputs and assumptions given, all of the 60 year harvest scenarios (4,5, and 6) result in a positive

NPV regardless of the discount rate or carbon price options used. By contrast, nearly all of the 100 year harvest scenarios (1,2, and 3) had a negative NPV. This shows that the time horizon is a key factor to profitability potential. As might be expected, the opportunity for positive NPV also has a strong dependence on discount rate. A higher discount rate correlated to lower profitability in the results due to the concentration of cost early in the life of the project and revenues later in the project. Another interesting observation is that in every case, the NPV increases with both select seed and fertilization treatments applied.

Also critical is how management on the ground is conducted. For example, were intensive treatments required prior to planting the site, the proponent would not only be in a prolonged deficit financially but also in the amount of time before the project would become a carbon sink. For example typical stand initiation forestry treatments often include herbicide treatments, mechanical site preparation, and burning slash and debris to increase plantability, survival, and early growth. These are all treatments that rapidly accelerate GHG emissions (Kurz 2009) and therefore work against the objective of making a project profitable. Logically then, choosing a site that can facilitate growth without intensive treatments will likely make the difference between profit and loss.

The stocking density is yet another variable in the modelling inputs that could have an impact on results. The density of 1600 stems per hectare is commonly used in timber analysis and in industrial planting operations in managing for timber resources but this is not necessarily optimal for carbon and forest products. Harvesting at 60 and 100 years were chosen arbitrarily for comparison purposes. In a real case study more modelling should be done determine what an optimal planting density would be as well as the optimal timing of harvest.

Other factors that would also have some bearing on the profitability of these types of projects would include real increases in land value and storage credit for carbon removed from the site and stored within long term forest products. If either of these possibilities were to factored into the analysis, it could alter the results substantially.

Results

In order to properly assess the option to directly invest in an afforestation project in the BC interior, land purchase price must be considered. The NPV from the financial analysis must exceed the cost of the land in order to make the project viable. A brief survey of land prices across the BC interior was used as a proxy for bare land values and converted to a price per hectare (see Table 4).

Table 4. Survey of Bare Land Prices Across BC Interior

Location	acres	price	hectares	$/ha
Quesnel	374	$ 219.00	151.4	$ 1,447
Quesnel	319	$ 295.00	129.1	$ 2,285
Penny	137	$ 64.00	55.4	$ 1,154
Nazko	280	$ 179.00	113.3	$ 1,580
Quesnel	590	$ 399.00	238.8	$ 1,671
Francois Lk	718	$ 750.00	290.6	$ 2,581
Peace	786	$ 790.00	318.1	$ 2,484
Houston	1642	$ 895.00	664.5	$ 1,347
Average	**605.8**	**$ 448.88**	**245.1**	**$ 1,818.62**

Source: http://www.bcfarmandranch.com/ and http://www.landquest.com/ accessed Feb. 27, 2010

With an average land asking price of $1818 per hectare at the time of the survey, it appears that none of the scenarios would match this price and make the project feasible. However there is one property (Penny) where land could be purchased for less than the expected NPV for only the best possible case of all scenarios (i.e. $1221 - $1154 = $67/ha NPV). Consider that this marginal profit would require a high price for carbon ($20/t) and a low expected return on investment (3% not considering inflation). Given this result, it is fair to assume that while there may be conditions that provide for a favourable project in the interior, there is much downside risk with even the most optimal conditions. As companies are looking to invest in projects that exceed their cost of capital, this screening analysis does not show land purchase and afforestation projects in the BC interior to be financially attractive. Therefore, for a firm to incorporate a direct investment approach such as this into their carbon strategy, it would be for reasons other than financial.

Conclusions

As some of the literature and the strategic analysis suggests, there are several benefits to making a conscious effort to manage carbon. The important questions are what to do and how much? To some extent Canadian companies are finding economic opportunities in producing energy from the biomass that once was considered a waste product. This is a logical first step. If forestry offset projects are considered the next step then the analysis would suggest that now is not the time to take this step. Therefore, unless carbon prices exceed $20/t C ($73.40/t $C0_2$) or bare land can be acquired at a considerable discount, a company might be further ahead to purchase carbon permits or credits on the open market than to invest directly in this type of project. Unless you were a first mover in land acquisition, scarcity might also limit investment opportunity and increase cost.

It is assumed that afforestation projects that are currently being conducted in the BC interior are likely speculating on excessive increases to carbon prices to make it a profitable venture. They may also be counting on additional factors such as real land value increases or acceptance of carbon removed and stored in forest products. Another possibility is that ex ante sales are being made at reasonable rates in the voluntary market meaning that the time risk is considerably less.

If a forest company were to pursue forestry carbon projects, the purpose may be for corporate social responsibility or to gain knowledge and experience in the carbon trading process, which would provide some value. If this were the desired strategy, a cautious approach should be taken. Because of the substantial risks over long time periods that are inherent in these projects, projects that look good on paper could turn bad very quickly. As the analysis shows, profit and loss are sensitive to discount rates, land costs, and carbon price.

Recommendations

Given these conclusions what would be the best approach for a forest company to take now to position itself for a low carbon future and improve their competitive position in the broader carbon market?

The answer to this question partly lies in what resources of a given company can be provided without the output of substantial capital. The opportunity to re-deploy human resources comes into play in creating these low cost solutions. Financial resources in the forest sector should increase over time according to market cycles and continued operational efficiencies. As the markets for forest products strengthen, retained earnings will provide companies internal capital to take further initiatives and reduce the need to finance carbon reduction initiatives with debt or equity offerings.

The company's first key initiative should be to establish its carbon footprint. This can be defined as, "The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide ($C0_2$)."[35] Without a baseline measure, it is impossible to quantify the impact of your actions and any potential benefits to the company that could be claimed in the future. Footprinting is a detailed but well-defined exercise that can be done by consultants or in-house staff that are given the time to learn the process, gather the required data, and work through the various calculations. Several resources are available to assist a business in working through the process.

Another simple yet important step is to set goals and targets around environmental stewardship metrics. Indicators may be monitored in much the same way that they are for operational goals and targets. The way that this will impact the organization is to create awareness throughout the workplace that environmental stewardship, in this case carbon footprint, is important to the company. As these values are consistent with public opinion, it will not be difficult to create this culture shift within the organization. It may begin with things as simple as recycling programs, or enhancing energy efficiency through various means. If these small improvements are promoted and heralded, it can create momentum for other initiatives that employees from all levels of the organization can become involved in. These initiatives would serve multiple purposes by saving money in material and energy costs, promoting employee engagement and relationships, while at the same time reducing the carbon footprint of the company.

Even though the financial analysis in this project did not favour forest offset projects in the BC interior, it is likely that other parts of the world hold much more promise. A Canadian firm may first want to look at the BC coast where site index and growing seasons are substantially higher and longer. To that end, more financial analysis is required to look at these options as well as those in other part of the world.

Two Paths

It is proposed that a company may take one of two approaches with respect to a comprehensive carbon strategy. The first would be a more conservative approach that would move toward a low-carbon future, albeit more gradually than the first movers of

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[35] http://timeforchange.org/what-is-a-carbon-footprint-definition

the industry. It would be more reactive to changes in market forces and legislation which would reduce both first mover advantages and downside financial risk. This strategy may be enacted by moving with an association such as FPAC that has a carbon-neutral agenda but also a large membership. This approach would not explore unproven technologies or direct investment in forest carbon projects.

The second approach would be characterized as one where a company would pursue a more aggressive strategy that would demonstrate more investment in green technologies, even some that are unproven. Direct investment in carbon forestry where there is a sound business case would also be explored. This approach must also include a strong public relations campaign in order to accept the benefits in terms of "social licence" through CSR activity. In order to not detract from the company's core business, investment in carbon projects should be done through either a committed reserve fund for that purpose or by creating a subsidiary company in order to protect it from being evaluated on the basis of the core business.

Regardless of which path is chosen, a conscious decision must be made and understood. The strategy selected should be sufficient to provide vision and guidance in order to prevent confusion and conflicting decisions at different levels of the organization. The worst decision would be ignore the problem in hoping that it will be resolved without intervention. Another pitfall would be to ride the fence and try to select a middle ground that tries to execute both approaches, but not be successful at either one. To conclude, an effective carbon strategy must be well thought out, espoused at the highest levels, and well communicated throughout the organization. This will be the basis for gaining employee commitment and successful implementation.

Bibliography

Black, T. Andrew, Rachhpal S Jassal, and Arthur L "Fredeen. Carbon Sequestration in British Columbia's Forests and Management Options" Pacific Institute for Climate Solutions, November 2008, Victoria, British Columbia, Canada

Burnett, Mike. "Corporate Strategies for Greenhouse Gas Reductions Should Include Carbon Offsets.", *Natural Gas & Electricity*; June 2006, Vol. 22 Issue 11, p13-17, 5p

Capoor, Karan and Philippe Ambrosi. "State and Trends of the Carbon Market 2009", The World Bank, May 2009, Washington, DC, USA

Dymond, C.C. and D.I. Spittlehouse. "Forests in a Carbon-constrained World", *BC Ministry of Forests and Range Extension Note* #92, November 2009, Victoria, BC, Canada

Forest Practices Branch, BC Ministry of Forests and Range. "British Columbia Forest Offset Protocol – Draft for Review". June 24, 2009

Greig, Mike and Gary Bull. "Carbon Management in British Columbia's Forests: Opportunities and Challenges" Forrex Forum for Research and Extension in Natural Resources, 2009, Kamloops British Columbia, Canada

Hamilton, Katherine, Unna Chokkalingam, and Maria Bendana. "State of the Forest Carbon Markets 2009: Taking Root and Branching Out". Ecosystem Marketplace, Jan 14, 2010

Heather, Keith, Brendan G. Mackey, and David B. Lindenmayer. "Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests" The Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Australia. Communicated by Gene E. Likens, Cary Institute of Ecosystem Studies, Millbrook, NY, March 9, 2009

Hoffman, Andrew J. John G. Woody. (2008) Climate change: what's your business strategy? Boston, Mass. : Harvard Business Press (Norwood, Mass. : Books24x7.com [electronic resource])

Hoffman, Andrew J. (2007) Carbon strategies : how leading companies are reducing their climate change footprint. Ann Arbor : University of Michigan Press

Hunger, J. David and Thomas L. Wheelen (2007) Essentials of Strategic Management (4th Edition) Pearson/Prentice Hall

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for policy makers of the climate change 2007: Synthesis Report. www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Jetté-Nantel, Simon. "Impact of a carbon market on afforestation incentives: a real option approach" Ottawa : Library and Archives Canada; 2007

Kull, Stephen. "CFS Forest Carbon Accounting News, January 26, 2009" email newletter received March 1, 2010

Kurz, Werner A. "Mitigation Strategies for the Forest Sector", Natural Resources Canada, Canadian Forest Service, BC Ministry of Forests Climate Change Seminar Series, April 16, 2009, Victoria, British Columbia, Canada

Laplume André O., Karan Sonpar and Reginald A. Litz. "Stakeholder Theory: Reviewing a Theory That Moves Us". *Journal of Management* 2008; 34; 1152

Lubowski, Ruben N., Andrew J. Plantinga, and Robert N. Stavins. "Land-use change and carbon sinks: Econometric estimation of the carbon sequestration supply function", *Journal of Environmental Economics and Management* 51 (2006) 135-152

National Roundtable on the Environment and the Economy - http://www.nrtee-trnee.com/eng/publications/carbon-pricing/carbon-pricing-eng.php

Natural Resources Canada forest carbon accounting - http://carbon.cfs.nrcan.gc.ca/FAQ_e.html accessed April 23, 2010

Newell, Richard G. and Robert N. Stavins. "Climate Change and Forest Sinks: Factors Affecting the Costs of Carbon Sequestration", *Journal of Environmental Economics and Management* 40, 211-235 (2000)

Petersen, Henry L., Juan Leonardo Espinoza, Luis Fernando Escobar, and Harrie Vredenburg. "Financing Technological Improvements and Firm Competitive Advantage Through the Kyoto Protocol's Clean Development Mechanism (CDM) A Latin American Example.", *Latin American Business Review*; 2005, Vol. 6 Issue 4, p23, 21p

Pinkse, Jonatan. "Corporate intentions to participate in emission trading.", *Business Strategy & the Environment (John Wiley & Sons, Inc)*; Jan2007, Vol. 16 Issue 1, p12-25, 14p, 5 charts

Pohjola, J.and Valsta, L. "Carbon credits and management of Scots pine and Norway spruce stands in Finland.", *Forest Policy & Economics*, Vol/Issue: 9 (7), Date: Apr 1, 2007, Page: 789

Porter, Michael E., "THE FIVE COMPETITIVE FORCES THAT SHAPE STRATEGY" *Harvard Business Review*, Jan2008, Vol. 86 Issue 1, p78-93, 16p

Porter, Michael E., Mark R. Kramer. "Strategy & Society: The Link Between Competitive Advantage and Corporate Social Responsibility". Harvard Business Review, Dec2006, Vol. 84 Issue 12, p78-92, 13p
Porter, Michael E. "What is Strategy?" *Harvard Business Review* Nov/Dec 1996

Raymer, Brian. "BC Forest Offset Protocol", web presentation, Ministry of Forests and Range, Research Branch, Victoria, BC, Nov 26, 2009

Rose, Adam and Shih-Mo Lin. "Regrets or no regrets - that is the question: is conservation a costless CO2 mitigation strategy?", *The Energy Journal*, July 1995 v16 n3 p67(21)

Sedjo, Roger. "Forest Carbon Sequestration: Some Issues for Forest Investments." (2005): *EconLit*. EBSCO. Web. 15 Dec. 2009.

Stavins, Robert N. "The Costs of Carbon Sequestration: A Revealed-Preference Approach", *The American Economic Review*; Sep 1999; 89, 4

Tavoni, Massimo, Brent Sohngen, and Valentina Bosetti. "Forestry and the carbon market response to stabilize climate", *Energy Policy*; Nov2007, Vol. 35 Issue 11, p5346-5353, 8p

Tvinnereim, E. and Roine K. "Carbon 2010 – Return of the Sovereign", Point Carbon 2010, 48 pages

Ximenes, Fabiano and Annette Cowie. *Outlook Conference Proceedings*; 2008, p1-9, 9p

Appendix I – PEST Diagram

Political-Legal Forces	Economic Forces
- Regional carbon trade framework can vary based on political will - Climate change focus currently reflected in proposed or approved legislation - cap and trade is the preferred mechanism for change - Canada criticized for being a laggard in climate change policy	- worldwide recession - longer downturn in forest industry - stimulus spending by governments to move to "green economy" - rise of BRIC nations
Societal Forces	**Technological Forces**
- population growth and pressures on land - heightened environmental awareness globally - worldwide concern about global warming - sharing of wealth is an issue between "rich" and "poor" countries.	- rapid technology changes worldwide - forest industry generally late adopters of technology advancements - forest industry research is primarily publicly funded and government led - trading markets appearing for voluntary and compliance carbon offsets - new wood products or new uses for by-products targeted toward energy sector

Appendix II – TOWS Matrix

TOWS MATRIX Strategies to use carbon forestry to add value to the company	**O - External Opportunities** 1. developing market 2. future market growth with cap and trade and recession recovery \$ 3. potential demand increase in 2011/12 to meet Kyoto committments 4. "green" marketing for existing products 5. gov't incentives	**T - External Threats** 1. climate change debate not over? 2. forestry firms financially inferior to other sectors 3. international uncertainty 4. worldwide recession
S - Internal Strengths 1. silviculture assets - seed orchards or nurseries 2. silviculture expertise 3. sustainable practices 4. operational efficiencies	1. Use human and/or facility resources to develop project for PCT (S1,S2,O1,O2,O4) 2. Explore product premiums for low carbon commitments (S3,O3) 3. Produce or buy pre-compliance credits to hold as appreciating assets (O1,O2)	1. Start with low investment projects (S1,S2,T1,T2,T3) 2. Partner with firms in other industries on larger projects (S1,S2,T2)
W - Internal Weaknesses 1. lack of private forest land ownership 2. short growing seasons 3. lack of experience 4. poor cash position	1. Start with projects that have win-win potential (W4,O4,O5) 2. Find partner on project in tropical or temperate zone (W1,W2,O1,O2,O5) 3. Partner with gov't with area-based tenures (W1,O4) 4. Develop expertise from consultants, new hires, or develop within (W3,O1,O2) 5. Use FIA funding to measure carbon footprint (W3,O4)	2. Benchmark those from other industries (W3,T2) 3. Look internally for low energy/emission solutions. (W3,W4,T1,T2,T3,T4)

Appendix III – TIPSY Inputs and Assumptions

All Scenarios

AGENCY : MOF Research Branch TIPSY Version 4.1d
PROJECT : Experimental SINDEX Version 1.42

STAND
GEOGRAPHY: Prince George/Prince George/SBS/5% Slope
ESTABLISHMENT: Regen delay = 0; Target Density = 1600 trees/ha (Planted)

SPECIES
100% LODGEPOLE PINE; Site Index = 20.00
Site curve: *Thrower (1994)
Top Ht @ bh age 50 (m) = 20.00 (base)
Stock ht = 13cm

HARVEST COSTS
Road Development
No Commercial Thinning Costs
Final Harvest: $1550.00/ha
Tree-to-Truck (Ground Skidding)
No CT Cost Adjustment
Distance to Support Centre: 100 km

Hauling: (Interior Equation/On Hwy: $5.26/m3)
Cycle Time: 3.0 hours
Added Transport Cost: $0.00

MILLING COSTS
(Exponential Equation/Interior)
Sawmill Capital Cost: $8.85/MBF

OTHER COSTS
Overhead: $3132/ha
Annual Costs: $0.00/ha
Other Harvest Costs: $0.00/m3

LUMBER PRICES/MBF
2x4 $431.00 2x6 $422.00 2x8 $429.00 2x10 $514.00 Chips $110.00/BDU

ECONOMIC SPECIFICATIONS (All revenues and costs are in constant 2001 Canadian dollars)
DISCOUNTING
Discount Rate: 4.0%
Analysis Base Age: 0 years

Real Price Increase: 0.0%
Real Cost Increase: 0.0%

Scenarios 1 and 4 – No Treatment and Harvest

SILVICULTURE COSTS (Total: $1111.90/ha)

Survey: $15.00/ha

Site Preparation: $485.00/ha

Planting: $611.90/ha

(includes $0/ha for improved seed)

No Brushing Costs

Total Regeneration Costs: $1111.90/ha

No PCT Costs

No Fertilization Costs

Other Treatments (at age 0) $0.00/ha

Total Silv. Treat. Costs: $0.00/ha

TIPSY Age (yr)	Top Ht (m)	Merch Vol. (m3/ha)	Harvest Revenue ($/ha)	Tree-to-Truck Cost ($/ha)	Haul Costs ($/ha)	Milling Cost ($/ha)	Average Revenue ($/m3)	Conversion Cost ($/m3)	NPV ($/ha)
0.0	0.1	0	0	0	0	0		-5794	
10.0	3.4	0	0	0	0	0		-4275	-13176
20.0	8.4	8	305	188	43	135	37.30	616.73	-3276
30.0	12.8	90	7564	1906	476	2580	83.65	106.65	-1753
40.0	16.4	196	19047	3550	1033	6314	96.98	79.32	-390
50.0	19.1	284	29967	4410	1492	9677	105.64	71.42	254
60.0	21.3	356	39274	4946	1872	12535	110.37	67.54	337
70.0	23.0	409	46435	5301	2151	14682	113.54	65.57	148
80.0	24.3	449	52260	5735	2362	16363	116.36	64.89	-109
90.0	25.5	485	57741	6109	2550	17907	119.09	64.45	-335
100.0	26.4	514	62450	6409	2706	19211	121.41	64.17	-529

Scenarios 2 and 5 – Fertilization and Harvest

SILVICULTURE COSTS (Total: $1411.90/ha)

Survey: $15.00/ha

Site Preparation: $485.00/ha

Planting: $611.90/ha

(includes $0/ha for improved seed)

No Brushing Costs

Total Regeneration Costs: $1111.90/ha

No PCT Costs

Fertilization #1 (age 25): $300.00/ha

Other Treatments (at age 0) $0.00/ha

Total Silv. Treat. Costs: $300.00/ha

TIPSY Age (yr)	Top| Ht| (m)|	Merch Vol. (m3/ha)	Harvest Revenue ($/ha)	Tree-to-Truck Cost ($/ha)	Haul Costs ($/ha)	Milling Cost ($/ha)	Average Revenue ($/m3)	Conversion Cost ($/m3)	NPV ($/ha)
0.0	0.1	0	0	0	0	0			-5794
10.0	3.4	0	0	0	0	0			-4275
20.0	8.4	8	305	188	43	135	37.30	616.73	-3276
30.0	13.2	100	8613	2090	528	2925	85.77	101.82	-1721
40.0	17.0	215	21344	3766	1133	7030	99.06	77.09	-239
50.0	19.7	303	32475	4578	1592	10436	107.28	70.33	350
60.0	21.9	376	41897	5052	1980	13347	111.29	66.57	376
70.0	23.7	429	49252	5517	2256	15502	114.86	65.20	143
80.0	24.9	469	55257	5941	2465	17208	117.90	64.64	-142
90.0	26.1	504	60769	6308	2653	18756	120.48	64.23	-393
100.0	27.0	534	65748	6603	2809	20103	123.14	64.05	-600

Scenarios 3 and 6 – Select Seed, Fertilization, and Harvest

SILVICULTURE COSTS (Total: $1459.90/ha)

Survey: $15.00/ha

Site Preparation: $485.00/ha

Planting: $659.90/ha

(includes $48/ha for improved seed)

No Brushing Costs

Total Regeneration Costs: $1159.90/ha

No PCT Costs

Fertilization #1 (age 25): $300.00/ha

Other Treatments (at age 0) $0.00/ha

Total Silv. Treat. Costs: $300.00/ha

Age (yr)	Top Ht (m)	Merch Vol. (m3/ha)	Harvest Revenue ($/ha)	Tree-to-Truck Cost ($/ha)	Haul Costs ($/ha)	Milling Cost ($/ha)	Average Revenue ($/m3)	Conversion Cost ($/m3)	NPV ($/ha)
0.0	0.1	0	0	0	0	0		-5842	
10.0	3.8	0	0	0	0	0		-4323	-13324
20.0	9.2	17	782	378	87	300	47.26	329.03	-3289
30.0	14.1	127	11460	2566	670	3856	89.95	92.42	-1369
40.0	18.1	251	25680	4111	1321	8375	102.25	73.62	225
50.0	20.8	340	37323	4854	1791	11931	109.62	68.31	707
60.0	23.1	413	47070	5350	2175	14867	113.85	65.48	628
70.0	24.7	461	54041	5858	2424	16865	117.29	64.74	282
80.0	26.0	503	60546	6295	2646	18695	120.35	64.24	-48
90.0	27.1	537	66279	6634	2825	20247	123.40	64.03	-338
100.0	28.1	568	71619	6935	2989	21681	126.02	63.85	-573

Appendix IV – CBM Modelling Outputs and Financial Analysis

Scenario 1 - Harvest at 100 Years, Sell Land

Time Step Years	Total Ecosystem (t/ha)	Biomass (t/ha)	DOM (t/ha)	Incremental Carbon Projected (t/ha)	Incremental Carbon Discounted (t/ha)	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
0	156.4759688	0	156.476	0	0	$ (529)	$ (529)	$ (529)
1	155.7293766	0.081369399	155.648	-0.74658217	-0.671932949	$ (3)	$ (7)	$ (13)
2	155.0880152	0.177653684	154.9104	-0.64136136	-0.577225228	$ (3)	$ (6)	$ (12)
3	154.5277208	0.287020223	154.2407	-0.5602944	-0.50426496	$ (3)	$ (5)	$ (10)
4	154.0684795	0.444354533	153.6241	-0.45924128	-0.413317154	$ (2)	$ (4)	$ (8)
5	153.6512188	0.601688939	153.0495	-0.41726076	-0.375534686	$ (2)	$ (4)	$ (8)
6	153.3572206	0.846790176	152.5104	-0.29399821	-0.264598392	$ (1)	$ (3)	$ (5)
7	153.1052475	1.102423706	152.0028	-0.25197301	-0.226775712	$ (1)	$ (2)	$ (5)
8	152.9712582	1.447136912	151.5241	-0.13398937	-0.120590434	$ (1)	$ (1)	$ (2)
9	152.9334267	1.858659627	151.0748	-0.03783152	-0.03404837	$ (0)	$ (0)	$ (1)
10	152.9849538	2.330480377	150.6545	0.05152716	0.046374443	$ 0	$ 0	$ 1
11	153.2466795	2.983198141	150.2635	0.26172572	0.235553147	$ 1	$ 2	$ 5
12	153.5359525	3.635915405	149.9	0.28927293	0.260345634	$ 1	$ 3	$ 5
13	154.1931497	4.621588847	149.5716	0.6571972	0.591477483	$ 3	$ 6	$ 12
14	154.9178215	5.632873699	149.2849	0.72467183	0.652204651	$ 3	$ 7	$ 13
15	155.9922622	6.947735514	149.0445	1.07446068	0.967014615	$ 5	$ 10	$ 19
16	157.3183496	8.459030883	148.8593	1.3260674	1.19346066	$ 6	$ 12	$ 24
17	158.8826835	10.15022392	148.7325	1.56433396	1.407900563	$ 7	$ 14	$ 28
18	160.9647826	12.29115845	148.6736	2.08209903	1.873889127	$ 9	$ 19	$ 37
19	163.1176075	14.43209424	148.6855	2.15282493	1.937542433	$ 10	$ 19	$ 39
20	165.9969014	17.22202995	148.7749	2.87929393	2.591364535	$ 13	$ 26	$ 52
21	168.9561095	20.03600431	148.9201	2.95920811	2.663287301	$ 13	$ 27	$ 53
22	172.2925959	23.19806901	149.0945	3.33648636	3.00283772	$ 15	$ 30	$ 60
23	175.8611942	28.55351953	149.3077	3.56859832	3.211738487	$ 16	$ 32	$ 64
24	179.5373901	29.97672779	149.5607	3.67619585	3.308576262	$ 17	$ 33	$ 66
25	183.3968158	33.54299488	149.8538	3.85942577	3.473483196	$ 17	$ 35	$ 69
26	187.2960505	37.10925985	150.1868	3.8992347	3.50931123	$ 18	$ 35	$ 70
27	189.7922638	39.26421102	150.5281	2.49621327	2.246591945	$ 11	$ 22	$ 45
28	192.2321604	41.3823715	150.8496	2.43989657	2.195906914	$ 11	$ 22	$ 44
29	194.6254003	43.46950635	151.1559	2.39323991	2.153915918	$ 11	$ 22	$ 43
30	196.9794676	45.52996402	151.4495	2.35406729	2.118660559	$ 11	$ 21	$ 42
31	199.8970476	48.15932788	151.7377	2.91758003	2.62582203	$ 13	$ 26	$ 53
32	202.7817595	50.75530819	152.0265	2.88471191	2.596240717	$ 13	$ 26	$ 52
33	205.6383159	53.32225219	152.3161	2.85655639	2.570900754	$ 13	$ 26	$ 51
34	208.4706844	55.86358837	152.6071	2.83234851	2.549113659	$ 13	$ 25	$ 51
35	211.282132	58.38209505	152.9	2.81148759	2.530320832	$ 13	$ 25	$ 51
36	214.0756327	60.88007658	153.1956	2.79350071	2.514150637	$ 13	$ 25	$ 50
37	216.8536818	63.35943392	153.4942	2.77802909	2.500226182	$ 13	$ 25	$ 50
38	219.6184003	65.82179371	153.7966	2.76473849	2.488264643	$ 12	$ 25	$ 50
39	222.3718063	68.26856316	154.1032	2.75340602	2.478065422	$ 12	$ 25	$ 50
40	225.1155747	70.70092351	154.4147	2.74376834	2.469391502	$ 12	$ 25	$ 49
41	227.4383625	72.71008333	154.7283	2.32278789	2.090509099	$ 10	$ 21	$ 42
42	229.7525107	74.71059244	155.0419	2.31414815	2.082733336	$ 10	$ 21	$ 42
43	232.0595549	76.70292627	155.3566	2.3070442	2.076339776	$ 10	$ 21	$ 42
44	234.3608125	78.68754752	155.6733	2.30125761	2.071131845	$ 10	$ 21	$ 41
45	236.6573867	80.66484945	155.9925	2.29657418	2.066916762	$ 10	$ 21	$ 41
46	238.9502572	82.63519482	156.3151	2.29287048	2.063583435	$ 10	$ 21	$ 41
47	241.2402882	84.59891504	156.6414	2.29003101	2.061027909	$ 10	$ 21	$ 41
48	243.5282556	86.55634896	156.9719	2.28796745	2.059170703	$ 10	$ 21	$ 41
49	245.8148194	88.50777686	157.307	2.28656376	2.057907385	$ 10	$ 21	$ 41
50	248.1006126	90.4534733	157.6471	2.28579325	2.057213921	$ 10	$ 21	$ 41
51	250.0310356	92.04128777	157.9897	1.93042295	1.737380651	$ 9	$ 17	$ 35
52	251.9583211	93.62557781	158.3327	1.92728556	1.734557005	$ 9	$ 17	$ 35
53	253.8833751	95.20643441	158.6769	1.92505396	1.73254856	$ 9	$ 17	$ 35
54	255.8069741	96.78397754	159.023	1.92359903	1.73123913	$ 9	$ 17	$ 35
55	257.7297319	98.35830338	159.3714	1.92275781	1.73048203	$ 9	$ 17	$ 35
56	259.6522729	99.92954183	159.7227	1.92254101	1.730286913	$ 9	$ 17	$ 35
57	261.5750068	101.4977734	160.0772	1.92273381	1.730460431	$ 9	$ 17	$ 35
58	263.4983603	103.0630869	160.4353	1.9233535	1.731018154	$ 9	$ 17	$ 35
59	265.4227027	104.6255921	160.7971	1.92434246	1.731908215	$ 9	$ 17	$ 35
60	267.3483168	106.1853254	161.163	1.92561409	1.733052682	$ 9	$ 17	$ 35
61	268.8615057	107.3317687	161.5297	1.51318887	1.361869987	$ 7	$ 14	$ 27
62	270.3714242	108.4768067	161.8946	1.50991856	1.3589267	$ 7	$ 14	$ 27
63	271.8790097	109.6204795	162.2585	1.50758545	1.356826906	$ 7	$ 14	$ 27
64	273.3849769	110.7627969	162.6222	1.50596718	1.355370466	$ 7	$ 14	$ 27
65	274.8899037	111.9037728	162.9861	1.50492677	1.354434093	$ 7	$ 14	$ 27
66	276.3943142	113.0434782	163.3508	1.50441055	1.353969496	$ 7	$ 14	$ 27
67	277.8985563	114.1819032	163.7167	1.50424212	1.353817906	$ 7	$ 14	$ 27
68	279.4029906	115.3190924	164.0839	1.50443432	1.353990889	$ 7	$ 14	$ 27
69	280.9078711	116.4550607	164.4528	1.50488046	1.354392418	$ 7	$ 14	$ 27
70	282.4134861	117.5898708	164.8236	1.50561496	1.355053483	$ 7	$ 14	$ 27
71	283.6396895	118.4455313	165.1942	1.22620345	1.103583104	$ 6	$ 11	$ 22
72	284.8630776	119.300528	165.5625	1.22338803	1.101049229	$ 6	$ 11	$ 22
73	286.0843783	120.1546906	165.9295	1.22130069	1.099170624	$ 5	$ 11	$ 22
74	287.3041034	121.0086224	166.2955	1.21972509	1.097752584	$ 5	$ 11	$ 22
75	288.5226773	121.8617075	166.661	1.2185739	1.096716513	$ 5	$ 11	$ 22
76	289.7404613	122.7141625	167.0263	1.21778401	1.096005611	$ 5	$ 11	$ 22
77	290.9577396	123.5660496	167.3917	1.21727831	1.095550479	$ 5	$ 11	$ 22
78	292.1747492	124.4172975	167.7575	1.21700961	1.095308646	$ 5	$ 11	$ 22
79	293.391708	125.2679593	168.1237	1.21695883	1.095262951	$ 5	$ 11	$ 22
80	294.6087754	126.1180557	168.4907	1.21706737	1.095360629	$ 5	$ 11	$ 22
81	295.7404183	126.8826379	168.8578	1.13164095	1.018476856	$ 5	$ 10	$ 20
82	296.8711968	127.6467593	169.2244	1.13078043	1.017702391	$ 5	$ 10	$ 20
83	298.001404	128.4104323	169.591	1.1302072	1.017186483	$ 5	$ 10	$ 20
84	299.1312559	129.1736502	169.9576	1.12985189	1.016866697	$ 5	$ 10	$ 20
85	300.2609212	129.9364098	170.3245	1.12966537	1.016698835	$ 5	$ 10	$ 20
86	301.3905949	130.6987502	170.6918	1.12967365	1.016706288	$ 5	$ 10	$ 20
87	302.5204105	131.4608593	171.0596	1.1298158	1.016834038	$ 5	$ 10	$ 20
88	303.6504429	132.2221158	171.4283	1.13003238	1.017029139	$ 5	$ 10	$ 20
89	304.7808498	132.9831771	171.7977	1.13040691	1.017366217	$ 5	$ 10	$ 20
90	305.9116704	133.7437967	172.1679	1.13082065	1.017738581	$ 5	$ 10	$ 20
91	306.8939269	134.3562301	172.5377	0.98225651	0.884030859	$ 4	$ 9	$ 18
92	307.8744963	134.9683856	172.9061	0.98056933	0.882512401	$ 4	$ 9	$ 18
93	308.8537485	135.5802736	173.2735	0.97925228	0.881327055	$ 4	$ 9	$ 18
94	309.8319959	136.191915	173.6401	0.97824738	0.880422645	$ 4	$ 9	$ 18
95	310.8094487	136.8033081	174.0061	0.9774528	0.87970752	$ 4	$ 9	$ 18
96	311.7862752	137.414436	174.3718	0.97682651	0.879143855	$ 4	$ 9	$ 18
97	312.762631	138.025299	174.7373	0.97635579	0.878720211	$ 4	$ 9	$ 18
98	313.7386758	138.6359326	175.1027	0.97604477	0.878440291	$ 4	$ 9	$ 18
99	314.7144611	139.2463024	175.4682	0.97578531	0.878206761	$ 4	$ 9	$ 18
100	234.0090264	0.081369399	233.9277	-80.7054327	-72.63488943	$ (363)	$ (726)	$ (1,453)

Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 100 ($/ha)	$ (529.0)		
Discount factor (risk of reversal)	10%		

	Discount rate		
	3%	5%	8%
NPV/ha @ $5/t	($339.53)	($412.64)	($455.01)
NPV/ha @ $10/t	($165.46)	($321.47)	($420.20)
NPV/ha @ $20/t	$182.67	($139.13)	($350.59)

Scenario 2 - Fertilize, Harvest at 100 Years, Sell Land

Time Step Years	Total Ecosystem (t/ha)	Biomass (t/ha)	DOM (t/ha)	Incremental Carbon Projected (t/ha)	Incremental Carbon Discounted (t/ha)	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
0	156.4759688	0	156.476	0	0	$ (600)	$ (600)	$ (600)
1	155.6127869	0.127208941	155.4856	-0.86318184	-0.77686366	$ (4)	$ (8)	$ (16)
2	154.9079094	0.277734936	154.6302	-0.70487753	-0.634389778	$ (3)	$ (6)	$ (13)
3	154.3249804	0.448713272	153.8763	-0.58292896	-0.524636064	$ (3)	$ (5)	$ (10)
4	153.8962853	0.694682015	153.2016	-0.42869515	-0.385825633	$ (2)	$ (4)	$ (8)
5	153.5302073	0.94065081	152.5896	-0.36607795	-0.329470159	$ (2)	$ (3)	$ (7)
6	153.3543724	1.323830048	152.0305	-0.17583487	-0.15825138	$ (1)	$ (2)	$ (3)
7	153.2421896	1.723474777	151.5187	-0.11218283	-0.100964543	$ (1)	$ (1)	$ (2)
8	153.3126633	2.262382568	151.0503	0.0704737	0.063426332	$ 0	$ 1	$ 1
9	153.5318852	2.905737107	150.6261	0.21922185	0.197299667	$ 1	$ 2	$ 4
10	153.8893771	3.643358886	150.246	0.35749188	0.321742693	$ 2	$ 3	$ 6
11	154.5743003	4.663785217	149.9105	0.6849232	0.61643088	$ 3	$ 6	$ 12
12	155.3014078	5.684211845	149.6172	0.72710759	0.654396829	$ 3	$ 7	$ 13
13	156.6027016	7.225164123	149.3775	1.30129396	1.171164561	$ 6	$ 12	$ 23
14	158.0084192	8.806157533	149.2023	1.40571736	1.265145625	$ 6	$ 13	$ 25
15	159.9597665	10.86174817	149.098	1.95134737	1.756212635	$ 9	$ 18	$ 35
16	162.3031321	13.22443451	149.0787	2.34336554	2.109028986	$ 11	$ 21	$ 42
17	165.0174976	15.86836176	149.1491	2.71436556	2.442929002	$ 12	$ 24	$ 49
18	168.5395999	19.2153927	149.3242	3.52210228	3.169892052	$ 16	$ 32	$ 63
19	172.1704162	22.56242676	149.608	3.63081633	3.267734698	$ 16	$ 33	$ 65
20	176.9349486	26.92407629	150.0109	4.76453233	4.288079097	$ 21	$ 43	$ 86
21	181.8184082	31.32330799	150.4951	4.8834596	4.395113636	$ 22	$ 44	$ 88
22	187.2827504	36.26672412	151.016	5.46434227	4.917908043	$ 25	$ 49	$ 98
23	193.1023663	41.51246631	151.5899	5.8196159	5.237654311	$ 26	$ 52	$ 105
24	199.0835323	46.86414698	152.2194	5.98116595	5.383049353	$ 27	$ 54	$ 108
25	205.3452538	52.4394734	152.9058	6.26172151	5.635549361	$ 28	$ 56	$ 113
26	211.6640583	58.01479675	153.6493	6.3188045	5.686924053	$ 28	$ 57	$ 114
27	215.9973192	61.5915503	154.4058	4.33326089	3.899934805	$ 19	$ 39	$ 78
28	220.244557	65.10827833	155.1363	4.24723782	3.82251404	$ 19	$ 38	$ 76
29	224.4204529	68.57440234	155.8461	4.17589592	3.758306332	$ 19	$ 38	$ 75
30	228.5363919	71.99702074	156.5394	4.11593894	3.70434505	$ 19	$ 37	$ 74
31	233.4485536	76.22238392	157.2262	4.91216175	4.420945571	$ 22	$ 44	$ 88
32	238.3113957	90.39664051	157.9148	4.86284202	4.376557821	$ 22	$ 44	$ 88
33	243.1320307	84.5262694	158.6058	4.82063506	4.338571558	$ 22	$ 43	$ 87
34	247.9165107	88.61647985	159.3	4.78447999	4.30603199	$ 22	$ 43	$ 86
35	252.6698794	92.67141688	159.9985	4.75336871	4.278031837	$ 21	$ 43	$ 86
36	257.3965803	96.69459106	160.702	4.72670085	4.254030781	$ 21	$ 43	$ 85
37	262.1004259	100.6889115	161.4115	4.70384566	4.233461092	$ 21	$ 42	$ 85
38	266.7847614	104.6568748	162.1279	4.68433551	4.21590196	$ 21	$ 42	$ 84
39	271.4525764	108.6006225	162.852	4.66781498	4.201033482	$ 21	$ 42	$ 84
40	276.1064485	112.5219827	163.5845	4.6538721	4.188484889	$ 21	$ 42	$ 84
41	279.8279567	115.5086104	164.3193	3.7215082	3.349357378	$ 17	$ 33	$ 67
42	283.5349716	118.4837664	165.0512	3.70701491	3.33631342	$ 17	$ 33	$ 67
43	287.2301065	121.4480095	165.7821	3.69513483	3.325621346	$ 17	$ 33	$ 67
44	290.9155186	124.4019231	166.5136	3.68541213	3.318870916	$ 17	$ 33	$ 66
45	294.5930494	127.3459812	167.2471	3.67753082	3.309777734	$ 17	$ 33	$ 66
46	298.2642953	130.280676	167.9836	3.67124587	3.304121286	$ 17	$ 33	$ 66
47	301.9305752	133.206416	168.7242	3.66627992	3.299651926	$ 16	$ 33	$ 66
48	305.5931024	136.1236074	169.4695	3.66252723	3.29627451	$ 16	$ 33	$ 66
49	309.2529168	139.0326187	170.2203	3.65981433	3.293832898	$ 16	$ 33	$ 66
50	312.9109626	141.933813	170.9771	3.65804588	3.292241291	$ 16	$ 33	$ 66
51	316.0714395	144.3347373	171.7367	3.16047688	2.844429189	$ 14	$ 28	$ 57
52	319.2266261	146.7306619	172.496	3.15518656	2.8396679	$ 14	$ 28	$ 57
53	322.3779721	149.1217671	173.2562	3.151346	2.836211398	$ 14	$ 28	$ 57
54	325.526573	151.5081897	174.0184	3.14860099	2.83374089	$ 14	$ 28	$ 57
55	328.6734425	153.8900894	174.7834	3.14686945	2.832182509	$ 14	$ 28	$ 57
56	331.819356	156.2675801	175.5518	3.1459135	2.831322148	$ 14	$ 28	$ 57
57	334.9650338	158.6408157	176.3242	3.1456778	2.83111002	$ 14	$ 28	$ 57
58	338.1110938	161.0099431	177.1012	3.14605995	2.831453958	$ 14	$ 28	$ 57
59	341.2580404	163.3750352	177.883	3.14694662	2.832251956	$ 14	$ 28	$ 57
60	344.4064254	165.7362981	178.6701	3.14838503	2.83354653	$ 14	$ 28	$ 57
61	346.905709	167.4482324	179.4575	2.49928358	2.249355221	$ 11	$ 22	$ 45
62	349.3988697	169.158199	180.2407	2.49316069	2.243844618	$ 11	$ 22	$ 45
63	351.8874355	170.8662671	181.0212	2.48856583	2.239709243	$ 11	$ 22	$ 45
64	354.3725323	172.5724531	181.8001	2.48509677	2.236587097	$ 11	$ 22	$ 45
65	356.8551612	174.2768408	182.5783	2.48262893	2.23436604	$ 11	$ 22	$ 45
66	359.3359809	175.9793867	183.3566	2.48081971	2.232737735	$ 11	$ 22	$ 45
67	361.8157203	177.6802236	184.1355	2.47973943	2.231765491	$ 11	$ 22	$ 45
68	364.2948092	179.3792959	184.9155	2.47908883	2.231179944	$ 11	$ 22	$ 45
69	366.7736986	181.0766587	185.697	2.47888939	2.231000449	$ 11	$ 22	$ 45
70	369.2528325	182.7724326	186.4804	2.47913395	2.231220559	$ 11	$ 22	$ 45
71	371.3135085	184.0511465	187.2624	2.06067596	1.854608368	$ 9	$ 19	$ 37
72	373.3690471	185.3289436	188.0401	2.05553865	1.849984789	$ 9	$ 18	$ 37
73	375.4204924	186.6058178	188.8147	2.05144523	1.846300707	$ 9	$ 18	$ 37
74	377.4687154	187.8818215	189.5869	2.04822306	1.843400751	$ 9	$ 18	$ 37
75	379.5143677	189.1569551	190.3574	2.04565227	1.841087043	$ 9	$ 18	$ 37
76	381.5579491	190.4312102	191.1267	2.04358137	1.839223231	$ 9	$ 18	$ 37
77	383.5999417	191.7046186	191.8953	2.04199266	1.837793398	$ 9	$ 18	$ 37
78	385.6406869	192.9771778	192.6635	2.04074515	1.836670636	$ 9	$ 18	$ 37
79	387.6805115	194.2489394	193.4316	2.0398246	1.835842141	$ 9	$ 18	$ 37
80	389.7196283	195.5198411	194.1998	2.03911678	1.835205103	$ 9	$ 18	$ 37
81	391.5982367	196.6312253	194.967	1.8786084	1.690747563	$ 8	$ 17	$ 34
82	393.4742349	197.7420232	195.7322	1.87599822	1.688398398	$ 8	$ 17	$ 34
83	395.3480979	198.8521934	196.4959	1.87386302	1.686476715	$ 8	$ 17	$ 34
84	397.2202567	199.9617661	197.2585	1.8721588	1.684942919	$ 8	$ 17	$ 34
85	399.0910121	201.0707439	198.0203	1.87075543	1.683679888	$ 8	$ 17	$ 34
86	400.9607038	202.1791848	198.7815	1.86969172	1.682722551	$ 8	$ 17	$ 34
87	402.8294731	203.287021	199.5425	1.86876922	1.6818923	$ 8	$ 17	$ 34
88	404.6975258	204.3942524	200.3033	1.86805273	1.68124748	$ 8	$ 17	$ 34
89	406.5650968	205.5009644	201.0641	1.86757105	1.680813944	$ 8	$ 17	$ 34
90	408.4323088	206.6071196	201.8252	1.86721197	1.680490777	$ 8	$ 17	$ 34
91	410.1399658	207.5548118	202.5852	1.707657	1.536891296	$ 8	$ 15	$ 31
92	411.8450714	208.5020994	203.343	1.70510554	1.534594988	$ 8	$ 15	$ 31
93	413.5516406	209.452522	204.0991	1.70656927	1.53591234	$ 8	$ 15	$ 31
94	415.2903638	210.435656	204.8547	1.73872321	1.564850893	$ 8	$ 16	$ 31
95	417.0289302	211.4182913	205.6106	1.73856634	1.56470971	$ 8	$ 16	$ 31
96	418.7675519	212.4005686	206.367	1.73862167	1.564759508	$ 8	$ 16	$ 31
97	420.506294	213.3824519	207.1238	1.73874217	1.564867955	$ 8	$ 16	$ 31
98	422.245168	214.3639075	207.8813	1.73887395	1.564986558	$ 8	$ 16	$ 31
99	423.984219	215.3449453	208.6393	1.739051	1.5651459	$ 8	$ 16	$ 31
100	298.9266621	0.127208941	298.7995	-125.057557	-112.5518012	$ (563)	$ (1,126)	$ (2,251)

Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 100 ($/ha	$ (600.0)		
Discount factor (risk of reversal)	10%		

	Discount rate		
	3%	5%	8%
NPV/ha @$5/t	($275.51)	($405.92)	($486.49)
NPV/ha @$10/t	$31.50	($240.41)	($417.43)
NPV/ha @$20/t	$645.53	$90.60	($279.31)

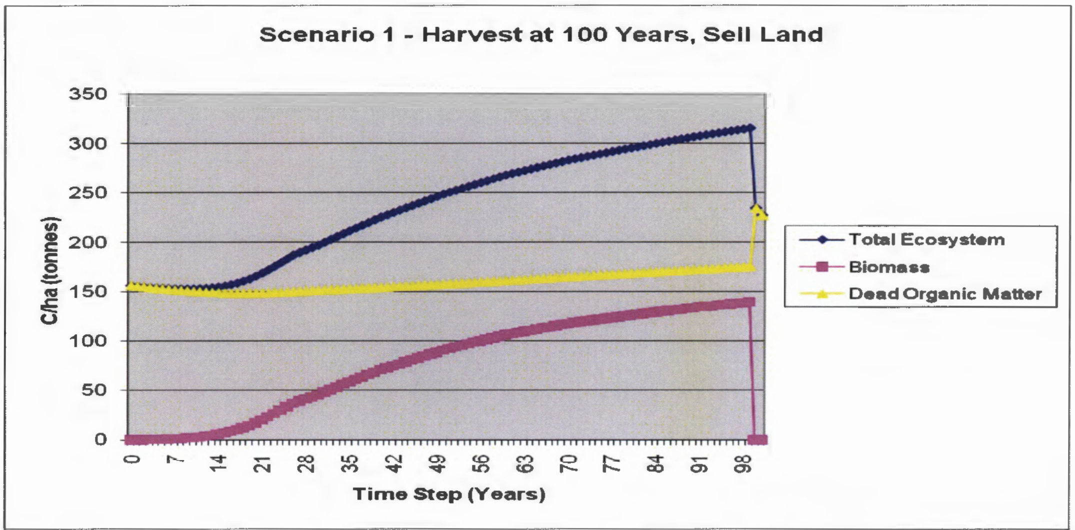
Scenario 3 - Select Seed, Fertilize, Harvest at 100 Years, Sell Land

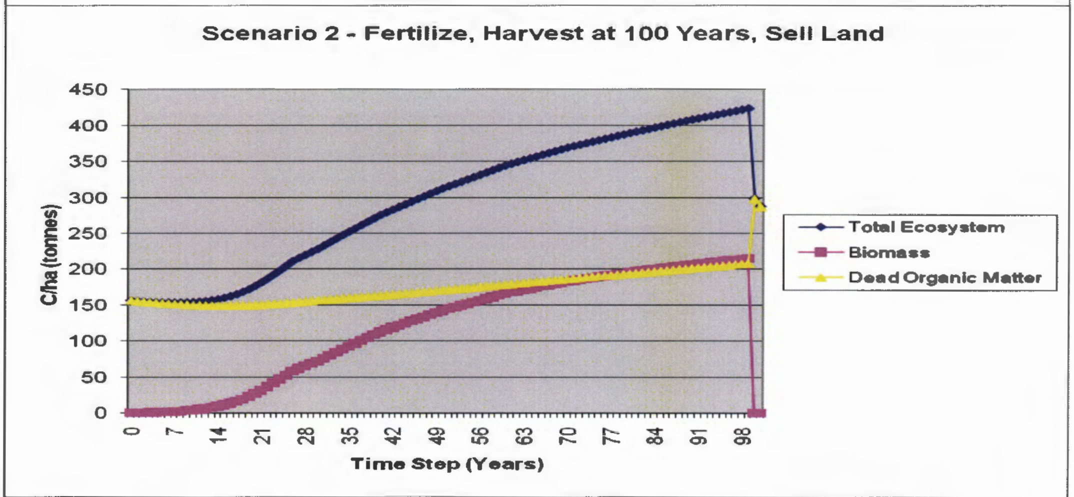
Time Step Years	Total Ecosystem (t/ha)	Biomass (t/ha)	DOM (t/ha)	Incremental Carbon (t/ha)	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
0	156.4759688	0	156.476	0	$ (573)	$ (573)	$ (573)
1	155.614289	0.128656834	155.4856	-0.861679786	$ (4)	$ (9)	$ (17)
2	154.9069569	0.276720898	154.6302	-0.707332102	$ (4)	$ (7)	$ (14)
3	154.3627944	0.485137634	153.8777	-0.544162478	$ (3)	$ (5)	$ (11)
4	153.9324457	0.727083366	153.2054	-0.430348723	$ (2)	$ (4)	$ (9)
5	153.6704536	1.071603302	152.5989	-0.261992074	$ (1)	$ (3)	$ (5)
6	153.5132897	1.464711426	152.0486	-0.157163889	$ (1)	$ (2)	$ (3)
7	153.5796489	2.029050675	151.5506	0.066359195	$ 0	$ 1	$ 1
8	153.7653024	2.661882431	151.1034	0.185653464	$ 1	$ 2	$ 4
9	154.2832749	3.572891968	150.7104	0.5179725	$ 3	$ 5	$ 10
10	154.9523425	4.576627929	150.3757	0.669067666	$ 3	$ 7	$ 13
11	156.1102485	6.013605896	150.0966	1.157905993	$ 6	$ 12	$ 23
12	157.4406626	7.568739837	149.8719	1.330414082	$ 7	$ 13	$ 27
13	159.4730665	9.755474549	149.7176	2.032403939	$ 10	$ 20	$ 41
14	161.726216	12.0795152	149.6467	2.253149493	$ 11	$ 23	$ 45
15	164.9079992	15.23348322	149.6745	3.181783187	$ 16	$ 32	$ 64
16	168.3391405	18.52577002	149.8134	3.431141297	$ 17	$ 34	$ 69
17	172.8162065	22.74215271	150.0741	4.477065936	$ 22	$ 45	$ 90
18	177.534321	27.06942847	150.4649	4.718114567	$ 24	$ 47	$ 94
19	183.1575033	32.16989392	150.9876	5.623182284	$ 28	$ 56	$ 112
20	188.9734289	37.32983655	151.6436	5.815925566	$ 29	$ 58	$ 116
21	195.1764839	42.80239612	152.3741	6.20305502	$ 31	$ 62	$ 124
22	201.4160993	48.28652917	153.1296	6.239615438	$ 31	$ 62	$ 125
23	206.7248817	52.83396557	153.8909	5.30878235	$ 27	$ 53	$ 106
24	211.8711306	57.23254199	154.6386	5.146248896	$ 26	$ 51	$ 103
25	216.8940415	61.52066566	155.3734	5.022910906	$ 25	$ 50	$ 100
26	221.8190231	65.72208899	156.0969	4.924981643	$ 25	$ 49	$ 98
27	226.6640674	69.8528036	156.8113	4.845044291	$ 24	$ 48	$ 97
28	231.4426432	73.92420032	157.5184	4.778575832	$ 24	$ 48	$ 96
29	236.1652412	77.94477771	158.2205	4.722597922	$ 24	$ 47	$ 94
30	240.8403107	81.92110096	158.9192	4.675069488	$ 23	$ 47	$ 94
31	245.9770126	86.35690477	159.6201	5.136701993	$ 26	$ 51	$ 103
32	251.0769238	90.74903468	160.3279	5.099911188	$ 25	$ 51	$ 102
33	256.1453975	95.10230886	161.0431	5.068473687	$ 25	$ 51	$ 101
34	261.1870252	99.42067297	161.7664	5.041627669	$ 25	$ 50	$ 101
35	266.2058431	103.707457	162.4984	5.018817952	$ 25	$ 50	$ 100
36	271.2054015	107.9654653	163.2399	4.999558318	$ 25	$ 50	$ 100
37	276.1887719	112.1970962	163.9917	4.983370433	$ 25	$ 50	$ 100
38	281.1587279	116.4044024	164.7543	4.969956042	$ 25	$ 50	$ 99
39	286.1177529	120.5892637	165.5285	4.959024937	$ 25	$ 50	$ 99
40	291.0680532	124.7532566	166.3148	4.950300281	$ 25	$ 50	$ 99
41	294.8346997	127.7298499	167.1048	3.766646511	$ 19	$ 38	$ 75
42	298.5881709	130.6968879	167.8913	3.753471277	$ 19	$ 38	$ 75
43	302.3312331	133.6548274	168.6764	3.743062173	$ 19	$ 37	$ 75
44	306.0660667	136.6040549	169.462	3.734833546	$ 19	$ 37	$ 75
45	309.7945519	139.5449858	170.2496	3.728485254	$ 19	$ 37	$ 75
46	313.5182203	142.4779282	171.0403	3.723668426	$ 19	$ 37	$ 74
47	317.2383673	145.4032273	171.8351	3.720146934	$ 19	$ 37	$ 74
48	320.9561865	148.3212305	172.635	3.717819257	$ 19	$ 37	$ 74
49	324.6725949	151.2321658	173.4404	3.716408377	$ 19	$ 37	$ 74
50	328.3884921	154.1363726	174.2521	3.71589721	$ 19	$ 37	$ 74
51	331.5799468	156.5135723	175.0664	3.19145469	$ 16	$ 32	$ 64
52	334.7664546	158.886531	175.8799	3.18650779	$ 16	$ 32	$ 64
53	337.9494676	161.2553699	176.6941	3.183012987	$ 16	$ 32	$ 64
54	341.1301535	163.6202127	177.5099	3.180685918	$ 16	$ 32	$ 64
55	344.3094636	165.9811687	178.3283	3.179310052	$ 16	$ 32	$ 64
56	347.4881814	168.3383232	179.1499	3.178717874	$ 16	$ 32	$ 64
57	350.6670746	170.6918484	179.9752	3.178893141	$ 16	$ 32	$ 64
58	353.8466706	173.0418059	180.8049	3.179596011	$ 16	$ 32	$ 64
59	357.0275288	175.3883042	181.6392	3.180858233	$ 16	$ 32	$ 64
60	360.2100928	177.731467	182.4786	3.182564002	$ 16	$ 32	$ 64
61	362.5869939	179.2703579	183.3166	2.376901075	$ 12	$ 24	$ 48
62	364.9554467	180.8078376	184.1476	2.368452805	$ 12	$ 24	$ 47
63	367.3173227	182.3439629	184.9734	2.361875962	$ 12	$ 24	$ 47
64	369.6740042	183.8787292	185.7953	2.356681494	$ 12	$ 24	$ 47
65	372.0266563	185.4122061	186.6145	2.352652121	$ 12	$ 24	$ 47
66	374.3761318	186.9443814	187.4318	2.349475575	$ 12	$ 23	$ 47
67	376.7231455	188.4752717	188.2479	2.347013671	$ 12	$ 23	$ 47
68	379.0682751	190.0048738	189.0634	2.345129547	$ 12	$ 23	$ 47
69	381.4120698	191.5332683	189.8788	2.34379476	$ 12	$ 23	$ 47
70	383.7549579	193.0604788	190.6945	2.342888125	$ 12	$ 23	$ 47
71	385.9049174	194.3957949	191.5091	2.149959469	$ 11	$ 21	$ 43
72	388.0517813	195.730188	192.3216	2.146863845	$ 11	$ 21	$ 43
73	390.1962723	197.0637278	193.1325	2.144491031	$ 11	$ 21	$ 43
74	392.3388188	198.3963391	193.9425	2.142546537	$ 11	$ 21	$ 43
75	394.4799621	199.7281338	194.7518	2.141143255	$ 11	$ 21	$ 43
76	396.6199899	201.0590425	195.5609	2.140027831	$ 11	$ 21	$ 43
77	398.7592794	202.389157	196.3701	2.139289461	$ 11	$ 21	$ 43
78	400.898	203.7183996	197.1796	2.138720608	$ 11	$ 21	$ 43
79	403.0364518	205.0468294	197.9896	2.138451859	$ 11	$ 21	$ 43
80	405.1747839	206.3744375	198.8003	2.138332011	$ 11	$ 21	$ 43
81	407.0583223	207.4485869	199.6097	1.883539415	$ 9	$ 19	$ 38
82	408.9382533	208.5222671	200.416	1.879931061	$ 9	$ 19	$ 38
83	410.8212963	209.6013833	201.2199	1.883042962	$ 9	$ 19	$ 38
84	412.7384147	210.7155085	202.0229	1.91711842	$ 10	$ 19	$ 38
85	414.6550985	211.8290913	202.826	1.916683741	$ 10	$ 19	$ 38
86	416.5715808	212.9421543	203.6294	1.916482354	$ 10	$ 19	$ 38
87	418.4879997	214.0547156	204.4333	1.916418855	$ 10	$ 19	$ 38
88	420.4044737	215.1667341	205.2377	1.916474055	$ 10	$ 19	$ 38
89	422.3210841	216.2782087	206.0429	1.916610424	$ 10	$ 19	$ 38
90	424.2379375	217.3891475	206.8488	1.916853354	$ 10	$ 19	$ 38
91	426.0562376	218.4016121	207.6546	1.818300071	$ 9	$ 18	$ 36
92	427.8733739	219.4137109	208.4597	1.817136295	$ 9	$ 18	$ 36
93	429.6895438	220.4253699	209.2642	1.816169928	$ 9	$ 18	$ 36
94	431.5049922	221.436623	210.0684	1.815448457	$ 9	$ 18	$ 36
95	433.3199334	222.4474878	210.8724	1.814941115	$ 9	$ 18	$ 36
96	435.1344506	223.4579263	211.6765	1.814517248	$ 9	$ 18	$ 36
97	436.9487555	224.4680242	212.4807	1.814304927	$ 9	$ 18	$ 36
98	438.7628057	225.4776526	213.2852	1.814050204	$ 9	$ 18	$ 36
99	440.5768003	226.4869363	214.0899	1.813994542	$ 9	$ 18	$ 36
100	308.393819	0.128656834	308.2652	-132.1829813	$ (661)	$ (1,322)	$ (2,644)

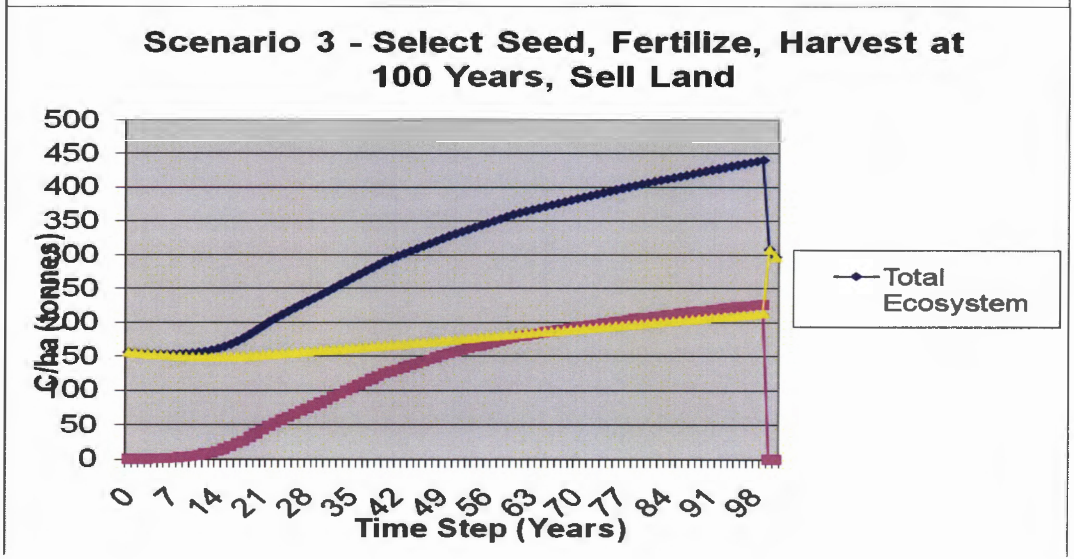
Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 100 ($/ha	$ (573.0)		

	Discount rate		
	3%	5%	8%
NPV/ha @$5/t	($173.98)	($332.05)	($435.38)
NPV/ha @$10/t	$208.35	($118.38)	($340.21)
NPV/ha @$20/t	$973.01	$308.95	($149.86)


Scenario 1 - Harvest at 100 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem
Biomass
Dead Organic Matter


Scenario 2 - Fertilize, Harvest at 100 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem
Biomass
Dead Organic Matter


Scenario 3 - Select Seed, Fertilize, Harvest at 100 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem

Scenario 4 - Harvest at 60 Years

Time Step Years	Total Ecosystem (t/ha)	Biomass (t/ha)	DOM (t/ha)	Incremental Carbon Projected (t/ha)	Incremental Carbon Discounted (t/ha)	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
0	156.4759688	0	156.476	0	0	$ 337	$ 337	$ 337
1	156.1292496	0.0813694	156.0479	-0.34672	-0.31205	$ (2)	$ (3)	$ (6)
2	155.8863515	0.17765368	155.7087	-0.2429	-0.21861	$ (1)	$ (2)	$ (4)
3	155.7231284	0.28702022	155.4361	-0.16322	-0.1469	$ (1)	$ (1)	$ (3)
4	155.6595593	0.44435453	155.2152	-0.06357	-0.05721	$ (0)	$ (1)	$ (1)
5	155.6365733	0.60168894	155.0349	-0.02299	-0.02069	$ (0)	$ (0)	$ (0)
6	155.7354745	0.84679018	154.8887	0.098901	0.089011	$ 0	$ 1	$ 2
7	155.8750252	1.10242371	154.7726	0.139551	0.125596	$ 1	$ 1	$ 3
8	156.1311833	1.44713691	154.684	0.256158	0.230542	$ 1	$ 2	$ 5
9	156.4821356	1.85865963	154.6235	0.350952	0.315857	$ 2	$ 3	$ 6
10	156.9210892	2.33048038	154.5906	0.438954	0.395058	$ 2	$ 4	$ 8
11	157.5688677	2.98319814	154.5857	0.647778	0.583001	$ 3	$ 6	$ 12
12	158.2428437	3.63591541	154.6069	0.673976	0.606578	$ 3	$ 6	$ 12
13	159.2833928	4.62158885	154.6618	1.040549	0.936494	$ 5	$ 9	$ 19
14	160.3900767	5.6328737	154.7572	1.106684	0.996015	$ 5	$ 10	$ 20
15	161.8452015	6.94773551	154.8975	1.455125	1.309612	$ 7	$ 13	$ 26
16	163.5506077	8.45903088	155.0916	1.705406	1.534866	$ 8	$ 15	$ 31
17	165.4929417	10.1502239	155.3427	1.942334	1.748101	$ 9	$ 17	$ 35
18	167.9517194	12.2911584	155.6606	2.458778	2.2129	$ 11	$ 22	$ 44
19	170.4798927	14.4320942	156.0478	2.528173	2.275356	$ 11	$ 23	$ 46
20	173.7332227	17.2220299	156.5112	3.25333	2.927997	$ 15	$ 29	$ 59
21	177.0651551	20.0360043	157.0292	3.331932	2.998739	$ 15	$ 30	$ 60
22	180.7730559	23.198069	157.575	3.707901	3.337111	$ 17	$ 33	$ 67
23	184.7117762	26.5535195	158.1583	3.93872	3.544848	$ 18	$ 35	$ 71
24	188.7567911	29.9767278	158.7801	4.045015	3.640513	$ 18	$ 36	$ 73
25	192.9837325	33.5429949	159.4407	4.226941	3.804247	$ 19	$ 38	$ 76
26	197.2492084	37.1092599	160.1399	4.265476	3.838928	$ 19	$ 38	$ 77
27	200.1103673	39.264211	160.8462	2.861159	2.575043	$ 13	$ 26	$ 52
28	202.9139332	41.3823715	161.5316	2.803566	2.523209	$ 13	$ 25	$ 50
29	205.6695634	43.4695064	162.2001	2.75563	2.480067	$ 12	$ 25	$ 50
30	208.3847439	45.529964	162.8548	2.715181	2.443663	$ 12	$ 24	$ 49
31	211.6621627	48.1593279	163.5029	3.277439	2.949695	$ 15	$ 29	$ 59
32	214.9054825	50.7553082	164.1502	3.2433	2.91897	$ 15	$ 29	$ 58
33	218.1193712	53.3222522	164.7971	3.213889	2.8925	$ 14	$ 29	$ 58
34	221.307792	55.8635884	165.4442	3.188421	2.869579	$ 14	$ 29	$ 57
35	224.4740913	58.382095	166.092	3.166299	2.849669	$ 14	$ 28	$ 57
36	227.6211728	60.8800766	166.7411	3.147081	2.832373	$ 14	$ 28	$ 57
37	230.7515335	63.3594339	167.3921	3.130361	2.817325	$ 14	$ 28	$ 56
38	233.867369	65.8217937	168.0456	3.115835	2.804252	$ 14	$ 28	$ 56
39	236.9706426	68.2685632	168.7021	3.103274	2.792946	$ 14	$ 28	$ 56
40	240.0630571	70.7009235	169.3621	3.092414	2.783173	$ 14	$ 28	$ 56
41	242.733276	72.7100833	170.0232	2.670219	2.403197	$ 12	$ 24	$ 48
42	245.3936373	74.7105924	170.683	2.660361	2.394325	$ 12	$ 24	$ 48
43	248.0456646	76.7029263	171.3427	2.652027	2.386825	$ 12	$ 24	$ 48
44	250.6906969	78.6875475	172.0031	2.645032	2.380529	$ 12	$ 24	$ 48
45	253.3298496	80.6648494	172.665	2.639153	2.375237	$ 12	$ 24	$ 48
46	255.9640951	82.6351948	173.3289	2.634245	2.370821	$ 12	$ 24	$ 47
47	258.5942921	84.598915	173.9954	2.630197	2.367177	$ 12	$ 24	$ 47
48	261.2212302	86.556349	174.6649	2.626938	2.364244	$ 12	$ 24	$ 47
49	263.8455889	88.5077769	175.3378	2.624359	2.361923	$ 12	$ 24	$ 47
50	266.467987	90.4534733	176.0145	2.622398	2.360156	$ 12	$ 24	$ 47
51	268.7338416	92.0412878	176.6926	2.265855	2.039269	$ 10	$ 20	$ 41
52	270.9953706	93.6255778	177.3698	2.261529	2.035376	$ 10	$ 20	$ 41
53	273.253489	95.2064344	178.0471	2.258118	2.032307	$ 10	$ 20	$ 41
54	275.5089839	96.7839775	178.725	2.255495	2.029945	$ 10	$ 20	$ 41
55	277.762493	98.3583034	179.4042	2.253509	2.028158	$ 10	$ 20	$ 41
56	280.0146043	99.9295418	180.0851	2.252111	2.0269	$ 10	$ 20	$ 41
57	282.2657652	101.497773	180.788	2.251161	2.026045	$ 10	$ 20	$ 41
58	284.5163909	103.063087	181.4533	2.250626	2.025563	$ 10	$ 20	$ 41
59	286.7668609	104.625592	182.1413	2.25047	2.025423	$ 10	$ 20	$ 41
60	229.500607	0.0813694	229.4192	-57.2663	-51.5396	$ (258)	$ (515)	$ (1,031)
61	168.2401953	0.0813694	168.1588	-61.2604	-55.1344	$ (306)	$ (613)	$ (1,225)

Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 60 ($/ha)	$ 337.0		
Discount factor (risk of reversal)	10%		

	Discount rate		
	3%	5%	8%
NPV/ha @ $5/t	$449.92	$411.76	$361.08
NPV/ha @ $10/t	$572.49	$502.51	$410.12
NPV/ha @ $20/t	$817.95	$684.12	$508.22

Scenario 5 - Fertilize, Harvest at 60 Years, Sell Land

Time Step Years	Total Ecosystem (t/ha)	Biomass (t/ha)	DOM (t/ha)	Incremental Carbon Projected (t/ha)	Incremental Carbon Discounted (t/ha)	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
0	156.4759688	0	156.476	0	0	$ 376	$ 376	$ 376
1	155.6127869	0.12720894	155.4856	-0.86318	-0.77686	$ (4)	$ (8)	$ (16)
2	154.9079094	0.27773494	154.6302	-0.70488	-0.63439	$ (3)	$ (6)	$ (13)
3	154.3249804	0.44871327	153.8763	-0.58293	-0.52464	$ (3)	$ (5)	$ (10)
4	153.8962853	0.69468201	153.2016	-0.4287	-0.38583	$ (2)	$ (4)	$ (8)
5	153.5302073	0.94065081	152.5896	-0.36608	-0.32947	$ (2)	$ (3)	$ (7)
6	153.3543724	1.32383005	152.0305	-0.17583	-0.15825	$ (1)	$ (2)	$ (3)
7	153.2421896	1.72347478	151.5187	-0.11218	-0.10096	$ (1)	$ (1)	$ (2)
8	153.3126633	2.26238257	151.0503	0.070474	0.063426	$ 0	$ 1	$ 1
9	153.5318852	2.90573711	150.6261	0.219222	0.1973	$ 1	$ 2	$ 4
10	153.8893771	3.64335889	150.246	0.357492	0.321743	$ 2	$ 3	$ 6
11	154.5743003	4.66378522	149.9105	0.684923	0.616431	$ 3	$ 6	$ 12
12	155.3014078	5.68421195	149.6172	0.727108	0.654397	$ 3	$ 7	$ 13
13	156.6027018	7.22516412	149.3775	1.301294	1.171165	$ 6	$ 12	$ 23
14	158.0084192	8.80615753	149.2023	1.405717	1.265146	$ 6	$ 13	$ 25
15	159.9597665	10.8617482	149.098	1.951347	1.756213	$ 9	$ 18	$ 35
16	162.3031321	13.2244345	149.0787	2.343366	2.109029	$ 11	$ 21	$ 42
17	165.0174976	15.8683618	149.1491	2.714366	2.442929	$ 12	$ 24	$ 49
18	168.5395999	19.2153927	149.3242	3.522102	3.169892	$ 16	$ 32	$ 63
19	172.1704162	22.5624268	149.608	3.630816	3.267735	$ 16	$ 33	$ 65
20	176.9349486	26.9240763	150.0109	4.764532	4.288079	$ 21	$ 43	$ 86
21	181.8184082	31.323308	150.4951	4.88346	4.395114	$ 22	$ 44	$ 88
22	187.2827504	36.2667241	151.016	5.464342	4.917908	$ 25	$ 49	$ 98
23	193.1023663	41.5124663	151.5899	5.819616	5.237654	$ 26	$ 52	$ 105
24	199.0835323	46.864147	152.2194	5.981166	5.383049	$ 27	$ 54	$ 108
25	205.3452538	52.4394734	152.9058	6.261722	5.635549	$ 28	$ 56	$ 113
26	211.6640583	58.0147967	153.6493	6.318805	5.686924	$ 28	$ 57	$ 114
27	215.9973192	61.5915503	154.4058	4.333261	3.899935	$ 19	$ 39	$ 78
28	220.244557	65.1082783	155.1363	4.247238	3.822514	$ 19	$ 38	$ 76
29	224.4204529	68.5744023	155.8461	4.175896	3.758306	$ 19	$ 38	$ 75
30	228.5363919	71.9970207	156.5394	4.115939	3.704345	$ 19	$ 37	$ 74
31	233.4485536	76.2223839	157.2262	4.912162	4.420946	$ 22	$ 44	$ 88
32	238.3113957	80.3966405	157.9148	4.862842	4.376558	$ 22	$ 44	$ 88
33	243.1320307	84.5262694	158.6058	4.820635	4.338572	$ 22	$ 43	$ 87
34	247.9165107	88.6164798	159.3	4.78448	4.306032	$ 22	$ 43	$ 86
35	252.6698794	92.6714169	159.9985	4.753369	4.278032	$ 21	$ 43	$ 86
36	257.3965803	96.6945911	160.702	4.726701	4.254031	$ 21	$ 43	$ 85
37	262.1004259	100.688912	161.4115	4.703846	4.233461	$ 21	$ 42	$ 85
38	266.7847614	104.656875	162.1279	4.684336	4.215902	$ 21	$ 42	$ 84
39	271.4525784	108.600623	162.852	4.667815	4.201033	$ 21	$ 42	$ 84
40	276.1064485	112.521983	163.5845	4.653872	4.188485	$ 21	$ 42	$ 84
41	279.8279567	115.50861	164.3193	3.721508	3.349357	$ 17	$ 33	$ 67
42	283.5349716	118.483766	165.0512	3.707015	3.336313	$ 17	$ 33	$ 67
43	287.2301065	121.44801	165.7821	3.695135	3.325621	$ 17	$ 33	$ 67
44	290.9155186	124.401923	168.5136	3.685412	3.316871	$ 17	$ 33	$ 66
45	294.5930494	127.345981	167.2471	3.677531	3.309778	$ 17	$ 33	$ 66
46	298.2642953	130.280676	167.9836	3.671246	3.304121	$ 17	$ 33	$ 66
47	301.9305752	133.206416	168.7242	3.66628	3.299652	$ 16	$ 33	$ 66
48	305.5931024	136.123607	169.4695	3.662527	3.296275	$ 16	$ 33	$ 66
49	309.2529168	139.032619	170.2203	3.659814	3.293833	$ 16	$ 33	$ 66
50	312.9109626	141.933813	170.9771	3.658046	3.292241	$ 16	$ 33	$ 66
51	316.0714395	144.334737	171.7367	3.160477	2.844429	$ 14	$ 28	$ 57
52	319.2266261	146.730662	172.496	3.155187	2.839668	$ 14	$ 28	$ 57
53	322.3779721	149.121767	173.2562	3.151346	2.836211	$ 14	$ 28	$ 57
54	325.526573	151.50819	174.0184	3.148601	2.833741	$ 14	$ 28	$ 57
55	328.6734425	153.890089	174.7834	3.146869	2.832183	$ 14	$ 28	$ 57
56	331.819356	156.26758	175.5518	3.145913	2.631322	$ 14	$ 28	$ 57
57	334.9650338	158.640816	176.3242	3.145678	2.83111	$ 14	$ 28	$ 57
58	338.1110938	161.009943	177.1012	3.14606	2.831454	$ 14	$ 28	$ 57
59	341.2580404	163.375035	177.883	3.146947	2.832252	$ 14	$ 28	$ 57
60	250.8136931	0.12720894	250.6865	-90.4443	-81.3999	$ (407)	$ (814)	$ (1,628)
61	242.4133205	0.27773494	242.1356	-8.40037	-7.56034	$ (306)	$ (613)	$ (1,225)

Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 60 ($/ha)	$ 376.0		
Discount factor (risk of reversal)	10%		

	Discount rate		
	3%	5%	8%
NPV/ha @$5/t	$546.11	$482.81	$409.90
NPV/ha @$10/t	$727.01	$607.48	$471.65
NPV/ha @$20/t	$1,089.14	$856.92	$595.15

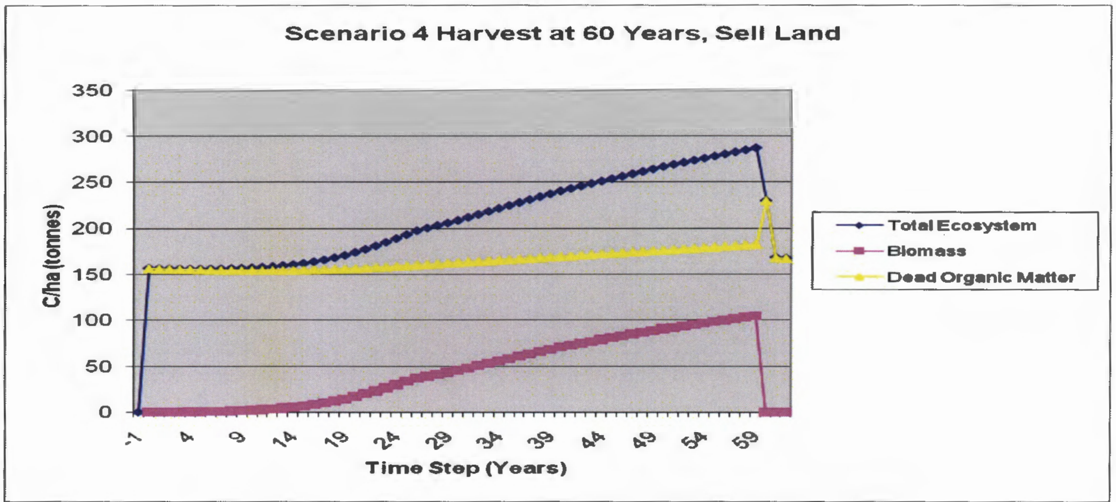
Scenario 6 - Select Seed, Fertilize, Harvest at 60 Years, Sell Land

Time Step	Total Ecosystem	Biomass	DOM	Incremental Carbon Projected	Incremental Carbon Discounted	Offset value at $5/t	Offset value at $10/t	Offset value at $20/t
Years	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)			
0	156.4759688	0	156.476	0	0	$ 628	$ 628	$ 628
1	155.614289	0.12865683	155.4856	-0.86168	-0.775512	$ (4)	$ (8)	$ (16)
2	154.9069569	0.2767209	154.6302	-0.707332	-0.636599	$ (3)	$ (6)	$ (13)
3	154.3627944	0.48513763	153.8777	-0.544162	-0.489746	$ (2)	$ (5)	$ (10)
4	153.9324457	0.72708337	153.2054	-0.430349	-0.387314	$ (2)	$ (4)	$ (8)
5	153.6704536	1.0716033	152.5989	-0.261992	-0.235793	$ (1)	$ (2)	$ (5)
6	153.5132897	1.46471143	152.0486	-0.157164	-0.141448	$ (1)	$ (1)	$ (3)
7	153.5796489	2.02905067	151.5506	0.066359	0.059723	$ 0	$ 1	$ 1
8	153.7653024	2.66188243	151.1034	0.185653	0.167088	$ 1	$ 2	$ 3
9	154.2832749	3.57289197	150.7104	0.517973	0.466175	$ 2	$ 5	$ 9
10	154.9523425	4.57662793	150.3757	0.669068	0.602161	$ 3	$ 6	$ 12
11	156.1102485	6.0136059	150.0966	1.157906	1.042115	$ 5	$ 10	$ 21
12	157.4406626	7.56873984	149.8719	1.330414	1.197373	$ 6	$ 12	$ 24
13	159.4730665	9.75547455	149.7176	2.032404	1.829164	$ 9	$ 18	$ 37
14	161.726216	12.0795152	149.6467	2.253149	2.027835	$ 10	$ 20	$ 41
15	164.9079992	15.2334832	149.6745	3.181783	2.863605	$ 14	$ 29	$ 57
16	168.3391405	18.52577	149.8134	3.431141	3.088027	$ 15	$ 31	$ 62
17	172.8162065	22.7421527	150.0741	4.477066	4.029359	$ 20	$ 40	$ 81
18	177.534321	27.0694285	150.4649	4.718115	4.246303	$ 21	$ 42	$ 85
19	183.1575033	32.1698939	150.9876	5.623182	5.060864	$ 25	$ 51	$ 101
20	188.9734289	37.3298366	151.6436	5.815926	5.234333	$ 26	$ 52	$ 105
21	195.1764839	42.8023961	152.3741	6.203055	5.58275	$ 28	$ 56	$ 112
22	201.4160993	48.2865292	153.1296	6.239615	5.615654	$ 28	$ 56	$ 112
23	206.7248817	52.8339656	153.8909	5.308782	4.777904	$ 24	$ 48	$ 96
24	211.8711306	57.232542	154.6386	5.146249	4.631624	$ 23	$ 46	$ 93
25	216.8940415	61.5206657	155.3734	5.022911	4.52062	$ 23	$ 45	$ 90
26	221.8190231	65.722089	156.0969	4.924982	4.432483	$ 22	$ 44	$ 89
27	226.6640674	69.8528036	156.8113	4.845044	4.36054	$ 22	$ 44	$ 87
28	231.4426432	73.9242003	157.5184	4.778576	4.300718	$ 22	$ 43	$ 86
29	236.1652412	77.9447777	158.2205	4.722598	4.250338	$ 21	$ 43	$ 85
30	240.8403107	81.921101	158.9192	4.675069	4.207563	$ 21	$ 42	$ 84
31	245.9770126	86.3569048	159.6201	5.136702	4.623032	$ 23	$ 46	$ 92
32	251.0769238	90.7490347	160.3279	5.099911	4.58992	$ 23	$ 46	$ 92
33	256.1453975	95.1023089	161.0431	5.068474	4.561626	$ 23	$ 46	$ 91
34	261.1870252	99.420673	161.7664	5.041628	4.537465	$ 23	$ 45	$ 91
35	266.2058431	103.707457	162.4984	5.018818	4.516936	$ 23	$ 45	$ 90
36	271.2054015	107.965465	163.2399	4.999558	4.499602	$ 22	$ 45	$ 90
37	276.1887719	112.197096	163.9917	4.98337	4.485033	$ 22	$ 45	$ 90
38	281.1587279	116.404402	164.7543	4.969956	4.47296	$ 22	$ 45	$ 89
39	286.1177529	120.589264	165.5285	4.959025	4.463122	$ 22	$ 45	$ 89
40	291.0680532	124.753257	166.3148	4.9503	4.45527	$ 22	$ 45	$ 89
41	294.8346997	127.72985	167.1048	3.766647	3.389982	$ 17	$ 34	$ 68
42	298.5881709	130.696888	167.8913	3.753471	3.378124	$ 17	$ 34	$ 68
43	302.3312331	133.654827	168.6764	3.743062	3.368756	$ 17	$ 34	$ 67
44	306.0660667	136.604055	169.462	3.734834	3.36135	$ 17	$ 34	$ 67
45	309.7945519	139.544986	170.2496	3.728485	3.355637	$ 17	$ 34	$ 67
46	313.5182203	142.477928	171.0403	3.723668	3.351302	$ 17	$ 34	$ 67
47	317.2383673	145.403227	171.8351	3.720147	3.348132	$ 17	$ 33	$ 67
48	320.9561865	148.32123	172.635	3.717819	3.346037	$ 17	$ 33	$ 67
49	324.6725949	151.232166	173.4404	3.716408	3.344768	$ 17	$ 33	$ 67
50	328.3884921	154.136373	174.2521	3.715897	3.344307	$ 17	$ 33	$ 67
51	331.5799468	156.513572	175.0664	3.191455	2.872309	$ 14	$ 29	$ 57
52	334.7664546	158.886531	175.8799	3.186508	2.867857	$ 14	$ 29	$ 57
53	337.9494676	161.25537	176.6941	3.183013	2.864712	$ 14	$ 29	$ 57
54	341.1301535	163.620213	177.5099	3.180686	2.862617	$ 14	$ 29	$ 57
55	344.3094636	165.981169	178.3283	3.17931	2.861379	$ 14	$ 29	$ 57
56	347.4881814	168.338323	179.1499	3.178718	2.860846	$ 14	$ 29	$ 57
57	350.6670746	170.691848	179.9752	3.178893	2.861004	$ 14	$ 29	$ 57
58	353.8466706	173.041806	180.8049	3.179596	2.861636	$ 14	$ 29	$ 57
59	357.0275288	175.388304	181.6392	3.180858	2.862772	$ 14	$ 29	$ 57
60	258.6681699	0.12865683	258.5395	-98.35936	-88.52342	$ (443)	$ (885)	$ (1,770)
61	249.8287697	0.2767209	249.552	-8.8394	-7.95546	$ (306)	$ (613)	$ (1,225)

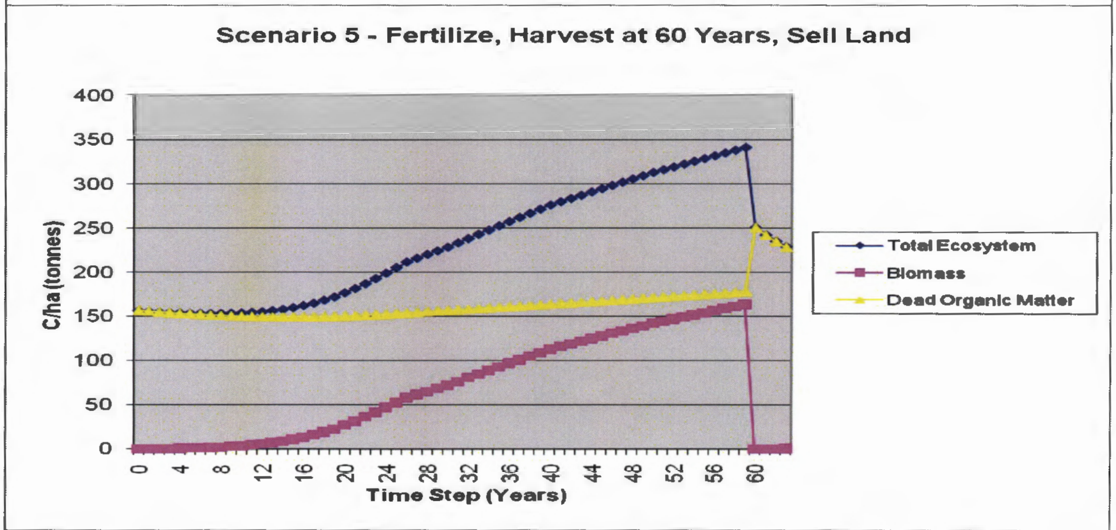
Assumptions

Carbon market price /t	$ 5	$ 10	$ 20
NPV for harvest at year 60 ($/ha)	$ 376.0		
Discount factor (risk of reversal)	10%		

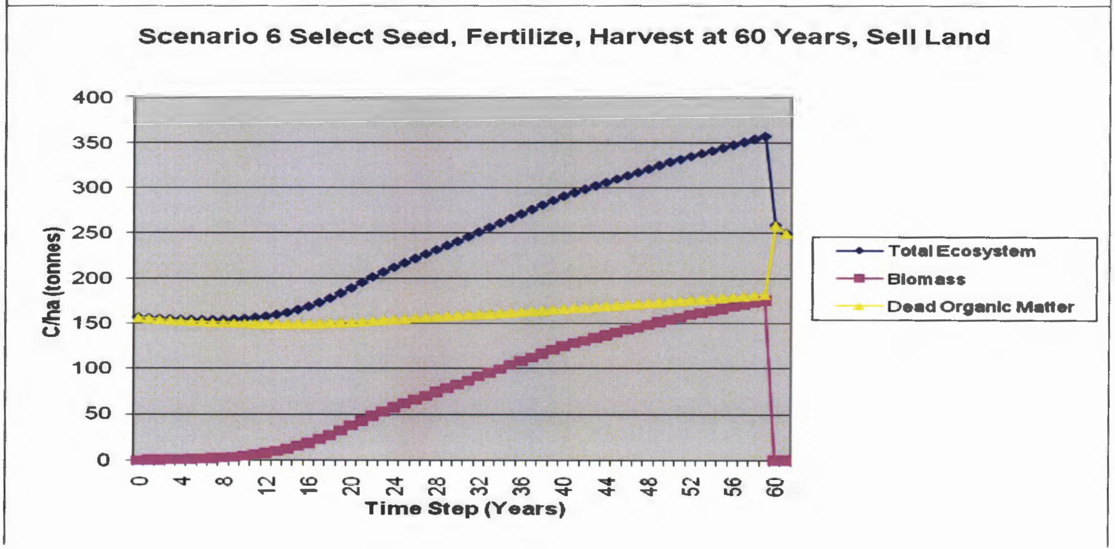
	Discount rate		
	3%	5%	8%
NPV/ha @$5/t	$823.63	$748.09	$659.54
NPV/ha @$10/t	$1,037.38	$898.03	$737.58
NPV/ha @$20/t	$1,465.22	$1,198.01	$893.69



Scenario 4 Harvest at 60 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem
Biomass
Dead Organic Matter



Scenario 5 - Fertilize, Harvest at 60 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem
Biomass
Dead Organic Matter



Scenario 6 Select Seed, Fertilize, Harvest at 60 Years, Sell Land
C/ha (tonnes)
Time Step (Years)
Total Ecosystem
Biomass
Dead Organic Matter